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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY,

ESTABLISHED NOVEMBER 13, 1807.

SECOND SERIES.

VOLUME I.

PART THE FIRST.

Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant.

Novum Organum, Præfatio.

LONDON:

PRINTED BY R. AND A. TAYLOR, SHOE LANE.

SOLD AT THE HOUSE OF THE GEOLOGICAL SOCIETY,
No. 20, BEDFORD STREET, COVENT GARDEN.

1822.

CHARTER

OF THE

GEOLOGICAL SOCIETY OF LONDON.

GEORGE *THE FOURTH*, by the Grace of God, of the United Kingdom of Great Britain and Ireland, King, Defender of the Faith.

To all to whom these presents shall come greeting. Whereas the Reverend William Buckland, B.D. Arthur Aikin, Esquire, John Bostock, M.D. George Bellas Greenough, Esquire, Henry Warburton, Esquire, and several others of our loving subjects, being desirous of forming a Society for investigating the Mineral structure of the Earth, and having for promoting such investigation expended considerable sums of money in the purchase and collection of Books, Maps, Specimens, and other objects, and in the publication of various works, the said William Buckland, Arthur Aikin, John Bostock, George Bellas Greenough, and Henry Warburton, have humbly besought us to grant unto them and unto such other persons as shall be appointed and elected Fellows of the Society as hereinafter is mentioned, Our Royal Charter of Incorporation, for the better carrying on the purposes aforesaid. Now therefore Know ye that we, being desirous to encourage so laudable an undertaking, have of our special grace, certain knowledge and mere motion, willed, ordained, constituted, declared, given and granted, and by these presents, Do for us, our Heirs and Successors, will, ordain, constitute, declare, give, and grant,

Purpose for which the Society is instituted.

That our loving subjects the said Reverend William Buckland, Arthur Aikin, John Bostock, George Bellas Greenough, and Henry Warburton, and such other persons as shall from time to time be appointed and elected Fellows of the said Society in manner hereinafter directed, and their respective successors, shall for ever hereafter be by virtue of these presents one body Politic and Corporate, by the name of " THE GEOLOGICAL SOCIETY OF LONDON." And we do will, constitute, and declare them and their successors to be one body Politic and Corporate, for the purposes aforesaid, and by the name aforesaid to have perpetual succession, and to have a Common Seal, with full power and authority to alter, vary, break and renew the same at their discretion, and by the same name to sue and be sued, to implead and be impleaded, and answer and be answered unto, in every Court, or place of us our Heirs and Successors.

Name of the Society.

And we do will, constitute, and grant, that the persons hereby incorporated, and their successors, shall be for ever able and capable in the Law, to purchase, receive, hold, possess, and enjoy, to them and their successors, any goods and chattles whatsoever, and (notwithstanding the statutes of Mortmain) to take, purchase, hold, and enjoy, to them and their successors, any lands, tenements, hereditaments, whatsoever, not exceeding, at the time or times of purchasing or acquiring such lands, tenements, or hereditaments respectively, the yearly value of Two thousand pounds in the whole, computing the same at rack rent which might have been had or gotten for the same respectively at the time of the purchase or acquisition of the same: And shall have full power and authority to sell, alien, charge, or otherwise dispose of, any real or personal property so to be by them acquired as aforesaid, and to act and do in all things relating to the said Corporation, in as ample manner and form as any other our liege subjects being persons able and capable in the Law, or any other Body Politic or Corporate in our said United Kingdom of Great Britain and Ireland, may or can act or do.

The first five Fellows who have power, for a time, to appoint other Fellows, and Foreign Members.

And we do hereby declare and grant, That the number of Fellows of the said Society shall be indefinite; and that they the said Reverend William Buckland, Arthur Aikin, John Bostock, George Bellas Greenough, and Henry Warburton, shall be the first Fellows of the said Society; and that any three or more of them shall and may, on or before the third Friday in February next ensuing the date of these presents, under their respective hands in writing, appoint such other persons to be Fellows and Foreign Members of the said society as are willing to be appointed, and as they may think fit.

President and Council.

First Council to consist of five Members: Future Councils of twenty-three Members.

And we do further declare and grant, That for the better government of the said Society, and for the better management of the concerns thereof, there shall be from the date of these presents, thenceforth and for ever, a President and Council of the said Society, and that such Council (whereof the President shall be deemed a Member,) shall from the date of these presents until the third Friday in February next ensuing, consist of Five Members; and from the said third Friday in February thenceforth and for ever, shall consist of Twenty-three Members.

First Council of five appointed and to remain in office till the third Friday in ~~May~~, 1826. Feb.

And we do hereby appoint the said Reverend William Buckland to be first President; and the said Reverend William Buckland, together with the said Arthur Aikin, John Bostock, George Bellas Greenough, and Henry Warburton, to be the first Council, all and each of the aforesaid persons to continue in such their respective offices until the third Friday in February next ensuing the date of these presents.

Future Councils of twenty-three how and when to be elected.

One-fifth or more to vacate annually.

And we further direct, That the Fellows of the said Society, or any Eleven or more of them, shall and may, on the said third Friday in February next ensuing, and also shall and may on the third Friday in February (or as near thereto as conveniently may be) in every successive year, assemble together at the then last or other usual place of meeting of the said Society, and by method of Ballot, remove from the then present Council one-fifth or more of the persons of whom it shall then be composed; And also shall and may, by the like method of Ballot, elect other persons, being Fellows of the said Society, into the Council, who together with the persons not so removed, shall form the Council for the then next ensuing year, so that the Members of such Council shall amount in number to twenty-three.

What officers are to be elected annually, and are to be also members of the Council.

And also, That the Fellows of the said Society, or any eleven or more of them, shall and may, at the time and in manner aforesaid, by the like method of Ballot, elect from among the Members of the Council, when formed and elected in the manner aforesaid, one person to be President of the said Society for the year ensuing, and so many and such persons as they shall think proper to be Vice-Presidents, Secretary or Secretaries, and Treasurer or Treasurers, of the said Society for the year ensuing.

Power to fill up vacancies in case of death.

And also shall and may, in case of the death of the President, or of any Vice-President, Secretary, or Treasurer, or of any other Member of the Council for the time being, of the said Society, within the space of two months next after such death, or as near thereto as conveniently may be, in manner aforesaid, elect some other person, being a Fellow of the said Society, to supply the place of such President, Vice-President, Secretary, Treasurer, or other Member of the Council so dying.

And we do further declare and grant, That from and after the said third Friday in February now next ensuing, the Fellows of the said Society, or any eleven or more of them, shall and may have the power, from time to time, at the General Meetings of the said Society, to be held at the usual place of meeting, or at such other place as shall have been in that behalf appointed, to elect by method of Ballot such persons to be Fellows and Foreign Members of the said Society, and such Fellows or Foreign Members to remove from the said Society as they shall think fit, and also shall and may from time to time nominate and appoint such persons as they shall think proper, to be Officers and Servants for carrying on and executing the necessary concerns of the said Society; and such Officers and Servants again to remove, and renew or restore, as they shall see occasion.

Power to elect new Fellows and Foreign Members,

and other Officers and Servants.

And we do further declare and grant, That from and after the said third Friday in February now next ensuing, the Fellows of the said Society, or any eleven or more of them, shall and may have the power to make and establish such Orders and Bye-Laws as shall appear to them useful for the government of the said Society for defining the powers to be entrusted to the Council, the President, and other Officers thereof; and the duties to be performed by such Officers respectively, for the management of the Estates, Goods, Lands, Revenues, and business of the said Society, and for the regulating the particular manner of proposing, electing, admitting and removing all and every the Fellows, Foreign Members, Officers, and Servants thereof; for fixing the times and places of the Meetings of the said Society; and also the Sum or Sums to be paid by the Fellows towards carrying on the purposes of the said Society; and the same Orders and Bye-Laws, from time to time, as they may see occasion to alter, suspend or repeal; and to make such new Orders and Bye-Laws in their stead as they shall think most proper and expedient, so as the same be not repugnant to these presents, or the laws of this our realm.

Power to make orders or Bye-laws.

And also, That the Council, or any five or more of the Fellows of the said Society, shall have power to move the enactment of any new Bye-Law, or the alteration, suspension or repeal of any existing Bye-Law, provided notice of such Motion shall have been delivered to one of the Secretaries in writing, and shall have been read from the Chair at two successive Meetings of the Fellows of the said Society; but that no such Motion shall be deemed or taken to pass in the affirmative until the same shall have been discussed and decided by Ballot at another Meeting summoned especially for that purpose, an absolute majority of the Fellows then present having voted in the affirmative. In Witness whereof, We have caused these our Letters to be made Patent.

Witness Ourself at our Palace at Westminster this Twenty-third day of April, in the Sixth Year of our Reign.

By Writ of Privy Seal,

(Signed) SCOTT.

London: printed by William Phillips, George Yard, Lombard Street.

NOTICE.

The Council of the Geological Society have recently taken upon themselves the charge and management of the publication of their Transactions, for the purpose of reducing the price, and thereby promoting the diffusion of Geological information. With this view they have adopted a page more full than that of the preceding volumes, and have employed Lithographic Plates instead of Engravings on Copper, wherever the substitution could be effected without injury to the correct illustration of the subjects represented.

As the Transactions of the Geological Society will thus assume a form in some measure new, the Council, for the convenience of purchasers, have determined to commence a New Series of volumes;—the portion now published being the First Part of Volume I. Second Series.

London,
June 21, 1822.

ERRATA.

P. 75, l. 21, *for* Hallirhoa *read* Hallirrhöe.
P. 111, l. 3 & 23, *for* left *read* right.

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ELECTED FEBRUARY 1, 1822.

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THE Editors of the Transactions of the Geological Society are directed to make it known to the Public, that the Authors alone are responsible for the facts and opinions contained in their respective papers.

It is requested that all letters and communications to the Secretaries, and presents to the Society, may be addressed to the House of the Geological Society, No. 20, Bedford Street, Covent Garden, London.

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CONTENTS.

The Binder is directed to observe, that the sheets of the present Volume (part of which was printed before the Society had determined on the commencement of a new series of volumes) are marked Vol. VI. instead of *Second Series, Vol. I.*

I.—*An Outline of the Geology of Russia.*

By the Hon. WILLIAM T. H. F. STRANGWAYS, M. G. S.

[Read March 2, 1821.]

BEFORE I enter on a subject of such magnitude as the Geology of Russia, I shall state in few words the plan I mean to pursue in treating it. The vast extent of the country, the little natural connexion of its different parts, and the impossibility of examining with sufficient minuteness the true geological relations of so great a variety of strata in any moderate period of time, prevent my being able to throw into any general system even those formations whose existence, extent, and characters are known to me. The country, however, is very naturally divided into districts, the geological features of which are so distinct, and their actual distance from each other at the same time so considerable, as to allow of their being described separately: were they not politically united, they would have little claim to be considered as the same country. After a short general view, therefore, I shall proceed to examine the details, each under its particular head.

The two great divisions of the empire, Russia properly so called, and Siberia, must be considered, geologically, as perfectly independent of each other; the same boundary dividing the two countries and the two tracts of secondary country belonging to them.

The empire, taken altogether, contains five principal mining districts; two in Europe, two in Asia, and one on the confines of Russia and Siberia. Those in European Russia are the northern or Finnish district, and the central: the former reaching from the Gulf of Bothnia to the Lake Onega; the latter stretching in an oblique direction across the country, from the government of Kalouga to that of Nishegorod *:—the metal principally worked is

* The correct name of this government, and of the town from which it derives its name, is Nishney Novgorod, familiarly abbreviated into the simple word Nishney, and frequently written Nishegorod. In each of these words the letters *sh* are pronounced hard, as the English *s* in the word *leisure*.

iron. The border or Oural district comprehends all the Oural mountains as far as they have been explored; in other words, the greatest part of the governments of Perm, Orenburg, and Viatka; that part of the chain which lies in the governments of Vologda and Archangel being scarcely known*.

The two mining districts which lie entirely within the frontier of Siberia are those of Kolyvan and Nerchinsk. That of Kolyvan is situated on the west frontier of China and of the Steppe of the Kirghis: that of Nerchinsk, beyond the Lake Baical, on the frontier of Siberia and China towards the Pacific Ocean.

The three last-mentioned districts afford almost every metal.

FINLAND†.

In traversing Russia from north to south, we find first a vast extent of primitive country, comprehending Russian Lapland, Finland, the northern parts of Carelia, and part of the government of Olonetz. Its boundary on the south may be taken as follows: The Gulf of Finland; from which we may suppose a line drawn from the Berezovsky Isles, and passing within forty versts of Wyborg quite across the Isthmus to the north shore of the Lake Ladoga above Kexholm: this line may be continued in the same direction across the lake to the north-eastern shore, whence it crosses another isthmus to the northern shore of the Lake Onega above Petrozavodsk: whence being continued still in the same direction, it terminates in the White Sea‡. It is evident that this primitive country is only a prolongation of that of Sweden, which it much resembles, and its connexion with which may be traced by the Isles of Åland in the south, by those in the centre of the Gulf of Bothnia, and by the Lapland chain of mountains into Norway on the north: it probably extends also by Nova Zemlia and the islands in the Icy Sea, to the northern extremity of

* See the Map. Plate II.

† *Finland.*—Under this title I comprehend the whole country of Old and New Finland and Carelia, which is still the popular name for those districts east of Wyborg: as far as the Carelian, a Finnish dialect is spoken. Under the Russian division this tract comprises the government of Abo, and the north parts of those of Wyborg and Olonetz.

‡ The southern outline of the granite takes a regular direction from south-east to north-west, from the south of Sweden to the north of Russia. The Pleta formation, as traced across the Baltic, is apparently parallel to the primitive, and co-extensive with it. The northern salt district and the Valday Hills also run in a parallel direction for nearly the same distance. The escarpments are regularly towards the north; rolled masses of each rock are found south of its native bed, but not to the north of it. Primitive boulders are found as far south as Moscow, but are rare in the eastern governments.

the Oural mountains. The northern parts* of this district are said to consist principally of trap rocks, the central of gneiss and other varieties of schistose rocks, while the southern border is entirely composed of granite. Even these subdivisions have their respective analogies with the different primitive formations of Norway and Sweden, and they affect a line of bearing nearly parallel to that of the whole district, as pointed out above. This will be better understood by a reference to the map. I will now mention some of the most remarkable places, beginning from the westward.

Pargas.—This name is given to a parish comprehending several considerable islands in the Gulf of Bothnia, about ten miles south of Abo. These islands present, in general, the same features as the main land; being usually long steep ridges of gneiss, crowned with fir trees and birch. In fact, they are but continuations of the hills of the continent, the valleys between which are above the level of the sea; while the channels between the islands may be considered as similar valleys below that level. The scenery is much more picturesque than it usually is in the inland parts of Finland, not only from the additional beauty of the water, and numerous vessels continually passing between Abo and the Baltic, but from the absence of those boggy plains which abound on the continent. The rocks, for the most part, are cut down perpendicularly, or nearly so, to the water's edge, leaving little or no strand at their foot. The soil on some of the larger islands is reckoned of a quality superior to that on the main land; those near the coast are generally inhabited; and the villages, farms, churches, and counting-houses of some of the wealthier inhabitants of Abo contribute not a little to embellish and enliven the scene.

On one of the principal islands of the parish of Pargas, but not that where the church and village are situated, from which the groupe derives its name, is found the mineral which has been called pargasite from its locality. It occurs in one or more large veins of milk-white primitive limestone, which traverse the whole island from side to side. This limestone, though rather too fragile and coarse-grained to deserve the name of marble, is nevertheless possessed of considerable beauty, both from the purity of its own texture and the brightness of colour of the various minerals it contains. It is sometimes clouded with a delicate yellow, sometimes with a bluish grey, (owing to the

* On the shores of the White Sea are found bunches of crystals of a sandstone resembling that of Fontainebleau, but of a browner colour. They usually appear to spring from a central ball, which is probably only the remains of a softer mass that once filled the space between the crystals, but is now washed out.

admixture of felspar,) and contains many large irregular veins of augite and of hornblende rock*, also the same substances disseminated through its mass in great abundance. Bright purple spots, supposed to be fluor, are common in some varieties; also moroxite, scapolite, coccolite, and Romantzovite: tourmaline occurs, but rarely. One of the most remarkable minerals of this rock is chondrolite; it is also one of the most plentiful. It possesses a much greater degree of hardness than the limestone, which is usually washed out of the surface of the weathered blocks, leaving only the yellow or orange-coloured mass of chondrolite behind. By this it appears, that in many cases where the chondrolite is thickly sown in the limestone, the grains, which on the fresh fracture appear to be insulated, do in fact touch one another in some point within, and are sufficiently connected to form a rugged but firm mass. This may be the case also with the other minerals. Chondrolite is found in many other parts of Finland, uniformly in primitive limestone. The pargasite itself has been so long known to mineralogists, and is described in so many periodical works, that a particular account of it here would be unnecessary; especially as the Society is in possession of the detailed memoir on pargasite published by Dr. Bonstorff of the university of Abo†.

The country through which the limestone vein passes is gneiss; the fissures of which are in a direction parallel to the course of the vein. Sometimes long narrow ridges or plates of gneiss are seen in the body of the limestone itself: these are easily detected, even on the surface, from the difference of colour and superior hardness to the mass in which they are imbedded, which causes them to project considerably above its level. The vein may be traced along the ground, where in many places it serves as a road, by its colour alone: its breadth varies from twenty to a hundred feet, and is quarried in five or six different places. Perhaps it should not, strictly speaking, be termed a vein; but as it seems to descend perpendicularly, and extends in an unbroken line with little or no change of direction, I adopt the name for want of a better‡.

Passing hence to the main land§, we observe that a gneiss, more or less

* One of these hornblende veins in one of the quarries near the western extremity of the Island, is represented in Plate I. fig 1. It is singularly interrupted.

† *Dissertatio Chemica, nova experimenta naturam Pargasitæ illustrantia proponens.* PP. I & II. Aboæ 1817—1818. This limestone of Pargas, both with respect to its geological situation and external character, seems to bear some analogy to that of the Hebrides, especially of the Isle of Tiree.

‡ At Abo it is called a Gang.

§ Another small island on this coast nearly opposite Bjorneborg is remarkable for rolled blocks of a fine-grained siliceous sandstone, of a yellowish colour, used for polishing glass. It is remarkable that a similar stone is found in the environs of Jönköping in Sweden, especially at Barnarp near the Taberg.

distinctly foliated, forms the most common rock of the country. To this, however, the stone of which consists the Rock of Abo, on which the observatory is placed, seems at first sight an exception. If viewed in hand specimens, or even large blocks detached from the rock, it appears to be rather a compact small-grained granite, of great hardness, abounding in garnets. But when viewed on the large scale, we see that the entire rock, as well as all the hills in the neighbourhood, is divided into layers, of great thickness indeed, but with a mutual parallelism and uniform dip. In this circumstance it agrees, not only with the nearest islands on the one hand, but on the other with the dip of some considerable hills up the valley on the road to Tavastchus.

To those who believe in the stratification of granite, few spots can offer so much satisfaction as the Rock of Abo *. Besides the regular lines which divide the beds, the beds themselves are readily distinguishable by their different colour, some being whiter, others of a redder or of a browner hue, but all equally studded with small garnets. The magnificent columns which adorn the interior of the public hall of the University of Abo, are single shafts cut from this rock; they bear a most brilliant polish.

The hills in this part of Finland are higher and more abrupt, and the valleys more fertile and infinitely better cultivated than those of the eastern districts. The hills are usually perpendicular where sections of the beds of rock are exposed to view, while on the opposite side, the back of the upper bed forms the gradual slope which conducts you to the bottom. Many are the secondary rocks whose inclination and escarpment are much less regular.

Near Tavastchus the granitic slates abound, frequently waved in the most singular and irregular manner. This is every where evident, owing to the absence of soil, which leaves patches of many square yards perfectly bare, on the top and sides of every hill. This circumstance is connected with another, namely, the peculiar roundness of all the hills and rocks, of which I shall say more hereafter. At Tamala, between this town and Abo, are glass-works supplied with flint from the rose quartz rocks of the neighbourhood; there is also found there a tabular variety of felspar.

At Orijerwy, near Helsingfors, is a copper mine, in which is found the blue quartz called steinhilite, also garnets, and primitive limestone. The latter is too valuable a material to be neglected in such a country as this.

* Near the summit of this rock I found a block of rose quartz and yellowish felspar; also a block of a blacker rock of the same composition as the rock of the hill, but which occurs *in situ* in a hill on the right bank of the river. This black variety was traversed by very thin white veins; the substance of the rock being turned red to a small distance on each side the vein throughout its entire length.

These slaty kinds of primitive rock, which may all be comprehended under the term granitic slate, seem to be continued in a north-easterly direction across the country to the neighbourhood of Wilmanstrand, not far from which, the river Voxa, flowing between banks of this substance, forms the rapids of Imatra, one of the grandest spectacles of the North, and which merit a particular description. I have, therefore, made it the subject of a separate paper*.

Still further to the eastward, is a finer slate, which is quarried in the hills which extend at a short distance from the north-west shore of the Lake Ladoga. Its colour is a deep black, and its texture is of the very finest quality. Although not yet in the general use which it merits, it is sometimes carried to Petersburg in large slabs for writing-tables.

In the same neighbourhood is also a garnet rock, said to resemble that of which boulders are found at Strelna. Higher up the country, near Cuopio, is found a species of potstone which is turned for bowls of pipes and other purposes; and also a black mica slate containing staurolite, boulders of which are found near Petersburg. At Nyslot is found rose quartz.

South of the tract above described, the primitive rocks lose entirely their schistose structure, and a true granite, perfectly free from any symptom of lamellar arrangement, prevails. Their general character may be described as glandular, better than by any other name, and is most conspicuous in the rocks around Wyborg †.

On a hill situated on the right bank of the river which runs by Borgo, and nearly opposite the town, is a tor of granite, in which red felspar predominates, spotted with small crystals of hornblende and black mica. Rolled masses of this rock are by no means uncommon in the neighbourhood of Petersburg. Between Borgo and Louisa are found boulders of jet black mica slate, both with and without garnets; the former variety is by far the hardest: also fragments

* Imatra is not the only remarkable waterfall on the Voxa: Turus or Turu Nemy is celebrated for the fall of Turoun kosky, immediately below which is the passage of the river. It is only fifteen versts from the post station of Kevy nemy, on the great road from Petersburg to Kexholm; and is close to the spot where the Voxa is crossed on the road from Kevy nemy to Raizela. Many other parts of this river, or chain of lakes, present interesting and picturesque scenery, especially in the neighbourhood of St. Peter and St. Andrus; the road by which villages, though only a cross road, is far superior to the best of the great roads of Russia.

There are two rapids at Imatra: the upper, where the Voxa issues from the Lake Saima; the lower, which is the most remarkable, a few versts further down the river. The latter I have described in another place.—*Geological Transactions*, vol. v. page 340.

† This granite may be well examined in the quarries belonging to Baron Nicolai, in an island in the Gulf of Wyborg, which furnished the great columns now seen in the Cazan Church at Petersburg.

of a yellowish or reddish hornstone, somewhat like a large rolled block of the same substance now on the shore of the Gulf of Finland, at Becova.

From Fredericshamn towards Wyborg *, and from Wyborg to the southward, as far as the granite can be traced *in situ,* it is distinguished by round or oval masses of reddish felspar of very regular appearance. Hornblende, which is plentiful, not only occurs mixed with the quartz between these portions of felspar, but is also disseminated through the felspar in small black spots. The felspar is sometimes dark red, sometimes pale pink or flesh-coloured, sometimes white or ash-coloured.

This, as is usual with most of the large-grained granites, is very liable to decomposition : instances of which may be seen frequently in Finland; where a great tor or boulder has often a hole cut in it large enough to admit a cart and horse; and the stone, though at a small distance it seems calculated to last for ages, is cut down and shaped away with the same ease and much in the same manner as a hayrick.

This granite is subject also to a different kind of decay, where large masses are separated by the winter frosts, in directions regulated by their prevailing fissures. These fissures are usually perpendicular, with horizontal ones crossing them at right angles, and at considerable distances, producing a sort of columnar arrangement on a large scale; not irregular, though ill defined. This structure may be traced every where on the surface of the rock, and affords bold and picturesque façades wherever the hill rises to a considerable elevation. North of Wyborg the country rises considerably, and in general, even in the flattest parts of Finland, are to be seen some of these abrupt rocks. They are too large perhaps to be called tors, but yet bear a considerable likeness to them. I will instance only a spot about three versts from Ehandola, on the road to St. Andrus, by the side of a small lake, as one of the best and most picturesque examples; and the perpendicular rocks which surround the beautiful cove called the Fins Haven, in the pleasure-ground of Monplaisir, the country house of Baron Nicolai, on an island in the Gulf of Wyborg.

I have before stated that towards the south the granite sinks beneath its own rubbish, and its ending is not known. It appears, however, in rocks on the Voxa between Imatra and St. Peter, and again between St. Peter and

* Between Fredericshamn and Wyborg is found a clay of a pale purplish colour, lying in the bottom of the valleys, and probably formed from the decomposition of the felspar after the disintegration of the granite. The great scarcity of lime in this part of Finland, makes this clay a valuable substitute for mortar to the peasantry, who use it as such, in the few buildings which they construct of stone.

St. Andrus. Its most southern known point is near Suvenoya, twenty versts from Wyborg.

The northern shore of the Ladoga is much broken and indented; its rocks present several varieties of red and grey veined marble, formerly much used at Petersburg: that of Reuscola was the most celebrated. Further eastward, near Cerdopol *, were formerly worked veins of sulphuret of copper, but I know not in what rock; of late some attempts have been made at working both copper and iron ores, higher up the country near Eno, but with indifferent success.

Nearly opposite Cerdopol, and at a considerable distance in the lake, is the Island of Valaam, famous for its monastery, and for a magnetic sand used in Petersburg for writing-sand; it is the largest island in the lake. North-east of Cerdopol is the Lake Shuya, near which was formerly worked a rich iron ore in veins, which has since been abandoned on account of the superior cheapness of the iron worked at Petrozavodsk, or procured in the same manner as at that place †.

The Lake Onega is bounded on its north-western shore by rocks of dark green jasper-breccia, on the north by a veined marble sometimes resembling that of Reuscola, sometimes greenish and full of tremolite, much like the marble of Glen Tilt. It is crystalline in its texture, and seems undoubtedly a primitive limestone. The western coast consists of a red sandstone of great hardness and solidity: this, as well as the breccia and marble above mentioned, is used in Petersburg as an ornamental stone. Blocks of the red sandstone are found over a large tract of country to the southward, comprehended between the Lake Onega, Petersburg, Moscow, and Kostroma ‡.

A striking resemblance may be traced in the features of the two lakes and of the Gulf of Finland. In each case, the northern shore is formed of the older rocks, is much broken and indented, and skirted with islands; and in each case the deep waters are found along those coasts. Sand or sandstone forms the east and west sides, and the necks of land which divide the respective basins. The southern boundary of each is a marsh, behind which, at a small distance, is a chain of hills of secondary limestone, of one and the same formation. The outlet of each is similarly situated; the Svir connecting the Lakes Onega and

* In the Swedish maps Sordivala.

† See hereafter, p. 10.

‡ I give these as the extreme known localities: of course there is no prescribing absolute limits to the rolling of a boulder. The red sandstone boulders of Uryavetz are studded with pebbles of white quartz, and are used as paving-stone at Nishne Novgorod. They are also found on the Oca.

Ladoga, in the same manner as the Neva connects the Lake Ladoga with the Gulf of Finland. The south shore is an even line, in both cases unaccompanied by islands, and the water for several miles out remarkably shallow; so much so, as in each instance to have made a canal necessary for the navigation.

There is probably a still greater difference of level between the Lakes Onega and Ladoga, than between the latter and the Gulf.

In a deep bay at the north-east extremity of the Lake Onega, is a small cluster of islands, one of which, called Volk Ostrof, or the Isle of Wolves, is celebrated for the beautiful minerals it affords*. Loose on the soil are found numerous blocks of a dark brown or black argillaceous ironstone, which, when broken, are seen to contain irregular cavities, lined with crystals of quartz, and oxyd of iron, of great variety and beauty. Sometimes the quartz becomes amethyst, and is at the same time penetrated by delicate tufts or pencils of oxyd of iron in radiating capillary crystals; sometimes the quartz itself is coated with yellow or red oxyd of iron; in the latter case it resembles in appearance the Hyacinth of Compostella. The yellow oxyd is often seen in small cubes; the black in fine acicular crystals. Some large blocks present cavities, each of which is lined with a different variety; others show all the varieties crystallized in the same group.

A glance at the map will suffice to throw together all I have said respecting this extensive tract of country. One circumstance, however, I must not omit. Throughout the whole of Finland, the evident traces of diluvian action are on the most astonishing scale. Without dwelling on the stupendous size and universal distribution of primitive boulders, it is impossible not to perceive, that the top of every rock *in situ,* every tor, every hill and knoll of granite, or primitive rock, from its first appearance in Carelia, till it sinks beneath the Gulf of Bothnia, presents a surface as much rounded, and as visibly water-worn, as the boulders or colossal pebbles that lie round their bases. Where the rock *in situ* does not rise high above the soil, and where the boulders are at the same time thickly scattered and of vast size, it is scarcely possible to distinguish one from the other. This is particularly the case between Wyborg and Fredericshamn, where they totally prevent the culture of the earth, and

* Some of these specimens are not unlike the nests of quartz crystals found in the neighbourhood of Bristol, often tinged red by iron. The acicular oxyd of iron is often found lining cavities in the ironstone of Mendip.

The blocks found on Volk Ostrof are evidently foreign to the island: their parent rock may perhaps be discovered hereafter in the almost trackless wilderness which extends north of the Lake Onega.

barely allow the passage of a carriage over a most tortuous and narrow road*. The islands off Abo possess the same rounded character: of course I do not mean those rocks whose summits are within reach of the sea which now surrounds them.

Another fact connected with this subject, and well worthy of remark, is, that in the south of Finland, where we recognise *in situ* the parent rocks of the commonest boulders of the neighbourhood of Petersburg, we find new varieties occurring in rolled masses, probably brought from rocks existing still further north. This circumstance much increases the interest attached to the primitive rocks in the north of Europe; since from this cause every rolled stone merits a certain degree of attention.

It remains only to mention the iron works of Petrozavodsk, by far the largest establishment of the kind in the north of Russia. The only sort of iron ore now smelted there is the bog iron ore, which abounds in its vicinity. The usual way of procuring it is to drag the small lakes, especially those north-west of Petrozavodsk, which yield vast quantites of the ore. It is not found equally spread over the bottom of all the lakes; often different points under the same sheet of water will afford ore of various degrees of purity. There are two great zavodes or manufactories of this iron; one four versts from Petersburg, on the Riga road; the other at Petrozavodsk; which place derives its name partly from that circumstance, partly from having been established by Peter the Great.

Specimens of plumbago have often been brought from different parts of Finland; but they are too coarse and too much mixed with grit to be serviceable.

Pleta District†.

South of this primitive range follows a very strong and regular formation of secondary rocks; the lowest of which is a pale greenish blue clay, which, it is probable, reposes immediately upon the granite or some

* This road however, in itself, is excellent, as are both the cross and great roads throughout all Finland.

† I have given this name to this extensive district from the principal bed contained in it; which also happens to be very centrally situated with respect to the whole formation, as far as it is contained within the Russian territory.

A suite of specimens of the strata constituting this formation is in the Museum at Oxford: some are also in the collection of the Geological Society; as are likewise similar specimens from the transition limestone of Plymouth, and from North America.

I have seen specimens of organic remains from the limestone of Shropshire, which are nearly identical in all their characters with those of the strata here described.

one of the older rocks last described. Upon this lies a sand or sandstone, of which, it has been imagined, the hard red grit of the west coasts of the Onega Lake is only a more compact form. In the neighbourhood of Petersburg this sand alternates with beds of shale, above which occurs a thick bed of limestone characterized by the same fossils which mark the limestones of Sweden and Norway, according to Von Buch. The clay and sand only have yet been found north of the Neva and Svir; the limestone follows the southern outline of the lakes, and skirts the two rivers above named. The sand and shale, together with the limestone, are distinctly stratified; the latter, with the sand, contains organic remains; both which characters are wanting in the clay.

These three strata, which I shall consider as making one formation, extend from the Baltic isles, which connect it with Sweden, through Esthonia*, the north of Livonia and Ingria, up to Vitegra, at the south-east corner of the Lake Onega. As I have given a more detailed account of it in another memoir, it will be unnecessary to enlarge upon it in this place.—*Vide Geological Transactions,* Vol. v. p. 293, &c.

NORTHERN SALT DISTRICT.

This formation, characterized in all parts of the globe by its striking features of red marl and sand, containing subordinate beds of sulphate of lime in every possible variety, as well as rock salt or saline springs, abounds in the central and southern parts of Russia. The northern salt district stretches in a line parallel to the Petersburg limestone mentioned above for one thousand versts; it makes its first appearance in the Isle of Osel, and is worked in several parts of the south of Livonia.

Gypsum is quarried at Dünahof, Uexhüll, and Kirchkolm. It is frequently of a dark brown colour, veined with white, and in that state takes a fine polish and is extremely beautiful, much resembling that called oriental alabaster.

* The limestone of Reval contains pyrites, which is uncommon in that of Petersburg. At Arrosaar, near Fellin, it contains sulphuret of lead, together with blende, in nests. These minerals were worked there under the Swedish Government; but an attempt to reopen the mines in 1806 was unsuccessful. The same minerals have been found also in veins traversing the limestone of Reval.

This limestone exists also on the very edge of the salt district next described, at Seltza Posad, a village and post on the road from Novgorod to Pscov, and just within the border of the latter government; also, according to Güldenstädt, at Sukhlova, not far from Porkhof. Both localities are on the river Shelon.

True alabaster, however, has only yet been found in Osel. The sand which constitutes the greatest part of Livonia has more consistence, and is more properly called a sandstone, than that of the government of Novgorod, with which it is naturally connected, both as accompanying the gypsum formation, and as bounding the northern limestone on this side: it is therefore much better adapted for geological examination, and is shown to great advantage in the rocky valleys of the rivers Salis, Raune, Ruje, Ammat, and Aa. Near Treyden, on the latter river, it contains a cavern called the Gutmann's Höhle; another in the same rock is called the Teufel's Höhle. The gypsum of Livonia is exported in large quantities from Riga to Petersburg*.

The red ground, in a state varying between sand and marl, is continued through the government of Novgorod, and forms the valley or basin in which the lake Ilmen lies. On the west side of this lake salt springs occur in many places, of which it is necessary to mention only the principal, Starry Russ, or Staraia Rus, which gives name to the manufactory and district. The same formation extends across the lower part of the Msta, and across the Volkhof, where it is in a more sandy state. In the government of Vologda, it occurs in many places; the most distant of which towards the east is Cisolsk. Whether the Vologda salt district communicates with those of Perm on the east and of Costroma on the south, is not yet determined.

This may, perhaps, be the proper place to mention, that in this government, at about 700 versts from the town of Vologda there is found near the mouth of the Vim, district of Yarensk, a black bituminous slate called by the Russians Domanite. It resembles the Kimmeridge coal of Dorsetshire.

* Livonia may be considered as a flat country, although some few hills attain a considerable elevation. It is remarkable that none of the principal eminences belong to the calcareous ranges by which the flat or sandy part of the country is bounded on the north and south; but rise insulated from the plain, and consist of the same sand and sandstone as the country below them. The best information respecting this country is to be found in Bray's *Hist. de Livonia,* vol. iii. also in two little works published at Riga,—*Livona,* and *Livona's Blumenkranz.*

Below are some measurements of the principal hills (from Bray's work).

Teufelsberg, near Laitzen, . .	860 French feet	above Riga.
Sestu Kaln, near Aselhof, . .	650	above Riga.
Plain of Serben	539	above Riga.
Munna Meggi (Egg-hill) . .	806 Rhenish feet above the lake of Werro, probably 1000 above the Baltic.	
Wölla Meggi	766	
Blauberg, a single hill, . . .	544 French feet.	
Gaysekaln (Himmelsberg or Fehsenberg), supposed to be higher than all.		

In the languages of the country, *Berg* in German, *Kaln* in Lettonian, *Meggi* in Esthonian, signify Hill.

VALDAY HILLS.

The valley of Novgorod is bounded on the south by the ridge of the Valday Hills, the most considerable regular chain between the Baltic and the Black Sea. It is possible that they may yield, in point of elevation, to the hills which accompany the right bank of the Volga during the middle part of its course; but as the Valday Hills form the ridge which throws off the waters, on the one side into the southern, and on the other into the northern basins, they make a more important feature in the physical map of Russia. They probably do not exceed eight or nine hundred feet in height; an inconsiderable elevation for the centre of so vast a country, and which will seem the more remarkable if we observe the magnitude of the streams which flow on either side from this nucleus. From the western extremity the Düna flows into the Baltic, and the Dniepr into the Black Sea: at a short distance to the eastward rises the Volga, which conveys all the waters of eastern and central Russia into the Caspian. Many inferior rivers flow from the northern slope into the three lakes, Ilmen, Ladoga, and Onega, all which empty themselves by the Neva into the Gulf of Finland. Towards the eastern extremity of the ridge the river Dina* collects all the smaller streams of the northern basin, and flowing to Archangel throws itself into the White Sea.

The escarpment of the Valday Hills is greatest towards the north. Though sandy, the soil is tolerably good, and the country is generally cleared and cultivated. These hills derive their name from the town and monastery of Valday, on the road from Moscow to Petersburg, and nearly midway between the two cities. The situation of the monastery on an island in the middle of a lake, and surrounded with wood, is wild and picturesque, particularly when viewed from a steep hill on the Borovichy road. Between Valday and Borovichy the hills are steep; but it is not till the deep channel of the Msta lays open their internal formation, that any trace of the limestone or coal, reputed to exist in this tract, makes its appearance. The clean and thriving town of Borovichy is situated on the Msta, just where that river quits the Valday Hills to enter into the plain of Novgorod. It is noted for the falls or rapids, which in this

* This river, and that which flows by Riga, are both spelt and pronounced in Russian *Dina*. The Livonian river I have written above Düna, according to the spelling adopted in the language of the country (German). That which flows into the White Sea I must therefore spell as I have done in the text. Both rivers are often incorrectly spelt Dwina or Dvina. Güldenstädt, though a German, seems to prefer *Dina* to *Düna*, yet by a strange inconsistency calls the lake, which is its source, *Dwinez*. vol. i. p. 19.

place impede the navigation of one of the principal channels of communication between the northern and central governments of Russia. Immediately above the town the hills rise to a very considerable height, and are much more varied in their forms than in the neighbourhood of Valday. As the river, for nine or ten versts above the town, runs between lofty and precipitous cliffs, excellent sections of the strata are exposed, more particularly in three spots; the Upper Fall, the Lower Fall, and a sort of gorge in the hills between the lower fall and the town. This gorge I shall describe first, as it occurs first on quitting Borovichy. It is proper to say, that the only rock seen *in situ* on the banks of the river at Borovichy is a red and grey marbled clay; it resembles both the red marl of central Russia, and some of the coloured varieties of the Esthonian clay: its situation with regard to the vale of Novgorod would connect it apparently with the former. Unfortunately, where the sandstone and calcareous rocks begin, their point of contact with this clay was so completely obscured, at the time I was there, by fragments of chert and other stones in great quantity, that their relative situation was not distinguishable. On following up the banks of the river, only limestone or sandstone is seen forming its bed, where that becomes free from the accumulations of chert and gravel. In the town of Borovichy, a little below the church nearest to the bridge, and on the right bank, is a deposit of calcareous matter of a snowy whiteness (*Lac Lunæ*) at a considerable height above the level of the river.

A little above the town, where the first ridge of hills abuts against the stream, is a lofty perpendicular cliff, of which the upper part is a pale reddish sand, which, some feet lower down, presents large patches of a bright yellow and white loose siliceous sand, resembling that on the Ishora near Petersburg. This sand appears to contain sulphur. Below this is a black sandy clay, intimately mingled with pyrites, which accompanies a bituminous clay bed that has long passed in the neighbourhood for a sure indication of coal. Connected with this pyrites and coaly clay, is a rugged ironstone containing charred wood; a fossil which also occurs in small fragments entangled in white calcareous spar lining cavities in the rock. There appear to be two thin beds of the bituminous clay in this place, one above the fine white sand, the other but little above the water's edge. Flint, though not seen here *in situ*, is plentiful in detached pieces under the cliffs.

No good sections are seen for some distance above this spot; but as we approach what is called the lower fall, about six versts above Borovichy, the left bank presents a long perpendicular face to the river. Opposite the lower part of this cliff is a small flat, covered with rolled masses of rocks brought down by the river in its floods. The hills on the right bank sweep round this little plain, and, meeting the river opposite the upper end of the long cliff on the left bank, form a sort of gorge; which being much filled up with ledges of strata that cross from side to side, together with great accumulations of primitive boulders and fragments of the surrounding rocks, constitutes what is called the lower fall*.

The sand here appears in horizontal strata, containing thick and regular beds of an argillaceous ironstone, which is an agglomerate of charred wood and every sort of geode; it is mammillated on the surface, in which character and in colour it resembles the sandstone of the Popovca, and other streams near Petersburg, and in its whole appearance is like that near Helsingborg in Sweden; which, it is remarkable, is in a true coal country. Some of its concretions are coloured much like Egyptian pebbles, and appear to be siliceous. Above this is a reddish sand, which forms the most projecting point of the rock; below it a yellow sand, presenting a pseudo-stratified structure or cleavage, which forms a considerable angle with the true lines of its beds, when viewed in the mass. The next beds are a blue limestone, which continues to near the water's edge, containing madrepores like those of the mountain-lime in Northumberland. Still more abundant is a very peculiar sort of Briarean Pentacrinite, the joints of which are very minute, and at first scarcely perceptible to the eye of one who does not suspect their existence. Its manner of growth seems to have been panicled, not unlike that of millet, with an inclination to droop on one side. Impressions of large tufts of this pentacrinite cover the greatest part of the surface of these limestone strata, bending sometimes in one direction, sometimes in another. In the bed of the river, the ledges of rock show a yellower and more sandy variety of this limestone, in which I could not discover the madrepores, though the pentacrinites were as abundant as in the blue beds. The latter contain also quantities of fragments of large encrini, minute corallines, and other marine fossils, in which it resembles the limestones of Dudley in England and some of the varieties of the Pleta formation in Russia, before described. This blue limestone also contains those large terebratulites with very thick shells, so common in certain limestones of the neighbourhood of Moscow, but which I have never yet seen in the northern limestone district. Although the bituminous and pyritical clays do not appear in this place, yet I suspect this dark limestone to be very near them.

* Most of what are called Falls in the rivers of the north of Russia, are merely rapids, owing to a combination of obstacles such as are here described. In Russian, the word *paroghee* is applied to waterfalls of every description.

Immediately above this spot the river widens, and then contracts itself between wooded banks which afford no geological sections. About three versts above the lower fall is placed the village of Ouglova, probably so called from the coal, such as it is, which re-appears in the bank of the upper fall situated just below it *.

At the upper fall, the banks of the river are not so high as at the lower; nevertheless, as they afford sections of the limestone containing chert *in situ*, a circumstance of rare occurrence in general in Russia, they cannot fail to be interesting. Both the limestone and chert are varied with yellow and red patches, and pass gradually into each other. The limestone contains here not only the large terebratulites which I have before mentioned, but also fragments of encrini &c. like those of the limestone of the rivers Sas and Shelon. These also occur in the chert; but I could see no large or perfect fossils in the beds of that substance at this spot, although they are so common in the loose masses south of the Valday Hills. Below these beds the coal shale and pyrites re-appear at the water's edge. I found one flint in the bed of the river, slightly rolled, much resembling those of the English chalk, and containing a finger-shaped alcyonite.

The Msta is a river very important in the inland navigation of Russia, as it is not only the largest stream of these parts, but also cuts through the greatest part of the whole breadth of the Valday Hills, in the line where their height is greatest, and where it would have been extremely difficult to form a canal. It is also fortunate, that the Tvertza, which flows southward, and joins the Volga at Tver, rises not far from the source of the Msta; so that by a short canal which passes through Vishney Volochok, the communication between the Baltic and Caspian Seas has been easily effected. This is the principal line of water communication: but as the Msta is extremely shallow and much obstructed by rocks, and the Tvertza, though less impeded in its course, does not at all times of the year contain sufficient water for barks, it was necessary to supply it by artificial means. Locks, in the time of Peter the Great, to whom the opening of this navigation is due, were too expensive; especially as the declivity of the Tvertza is so rapid, that it would have required a vast number of them to keep up the water of that river between Vishney Volochok and Tver. This rapidity of the Tvertza is probably owing to its source being so near to the southern slope of the hills; although their slope on this side is less than on the north. The Msta, on the contrary, by its long course through a deep valley, is less rapid than might have been expected: and although the

* See Plate 1. fig. 2.

plain of Tver is probably at a higher level than that of Novgorod, there is reason to believe that the level of the Volga, even in this early part of its course, is extremely low. Since the rivers did not contain water enough, the simplest and most obvious remedy was to fill them, at least at stated times, for the passage of vessels towards Petersburg from the countries on the Volga: and it happens fortunately for this object, that this part of the Valday Hills abounds in small lakes; every one of which, within a district of about 200 versts in circumference, that either communicates naturally or can be made to communicate with the Tvertza or the Msta, is laid under contribution, and compelled to furnish, at certain periods, a known and regulated quantity of its waters for the supply of one or the other river during the seasons of navigation. For this purpose, all the water-courses within the district have been dammed up, and at each sluice is stationed a guard, whose duty it is to give daily notice of the increase of the waters at his post, to a superior officer, who is commonly placed in one of the three towns along the line of navigation. This information being regularly transmitted from every station within the two systems of waters of the Tvertza and the Msta, the officer can easily calculate whether the total bulk of all the waters collected will be sufficient to float the vessels that are ready to pass, and which usually wait for the intelligence at Tver. As soon as he has information that the waters have risen at each station to the necessary height, orders are sent to the vessels that are waiting, to be prepared to mount the river, and to each of the guards at their respective posts to open the sluices at a particular hour. The hours specified in the orders sent to each guard at the sluices are so calculated, that the water shall not all be let off at the same moment, but that the more distant ponds being opened at an earlier, and those nearer to the navigable river at a later hour, the great body of water shall be brought into the bed of the river at the same moment, if required; or, that, if more of it than is necessary should be ready, the full stream may be continued at a certain height as long as it will last.

The immense rush of water which on these occasions passes down the Tvertza renders it, of course, very difficult to ascend; but the bottom and sides being free from rocks, the barks pass without much danger. On the other hand, the passage down the Msta is reckoned extremely dangerous, and they never attempt to remount the stream. The impetuosity of the current in so deep and uneven a bed,—sometimes abruptly turning rocky points, or confined within narrow gorges, which often suddenly expand it to wide basins, and as suddenly contract again,—is yearly the cause of the wreck of a great number of these vessels, although built on a peculiar plan for the passage of the rapids. They are extremely flexible, and narrow in proportion to their length: and the merchandize is arranged in rows placed across the vessel, so as to leave a certain interval between each row. This, together with the flexibility of the bottom, enables them so far to yield to the current, that the greatest waves barely cause the tops of the rows of sacks, casks, or other merchandize, to touch each other. Were they set close together, the boats would probably break, or be upset. Signal staffs on the most conspicuous points give notice of the approach of the water and boats; when men, women, and children, flock from the neighbouring villages, to give any necessary assistance to those engaged in this perilous navigation. When the waters have subsided, the passage is stopped for the next three weeks or month, according to the dryness or wetness of the season, till sufficient water is collected to fill the rivers as before. And this is repeated at intervals during the whole summer.

Although the Msta, at these moments of its being enlivened by a sudden and as it were miraculous navigation, presents a most curious and interesting spectacle; yet it is at low water that it is best adapted for geological investigation, as its rocks are then more exposed. By going a day before the waters are let off, it may be observed at high and low water within a short space of time. Among the artificial parts of this communication, the canal and sluices of Vishney Volochok, which are on a very large scale, and lined with gray granite supplied by the boulders of the neighbourhood, must be particularly noticed.

From Borovichy the high country stretches in a north-easterly direction between Tikhvin and Oustioushna, where there exists a second water communication across it, by means of the rivers Sas and Mologa and their affluents, which approach within a short distance of each other and are joined by a canal. This line of junction between the districts on the Volga and those on the Lake Ladoga, as well as the road which accompanies it, is now under a system of progressive amelioration. The face of the country is hilly, but sandy; I could not discover the limestone any where *in situ*, although some loose blocks of it, together with pieces of chert, are to be seen in small quantities south of Choudzi *.

There is yet a third system of navigation at present in progress across this

* One of the most remarkable facts with regard to the central parts of Russia, is the quantity of siliceous boulders which are scattered over the governments of Moscow, Vladimir, Tver, and the neighbouring countries. They are found on the Valday Hills, but rarely north of them, although they occur there *in situ*: a strong proof of the direction of the diluvian current from north to south. They resemble in general the chert of the mountain lime, and contain terebratulites, caryophyllites, entrochites, astroites, meandrites, and many other marine fossils, beautifully preserved and frequently agatized. They are rarely found north of the town of Valday, or east of Kostroma. Their boundary on the south and west is unknown.

high level, to the east of those I have already mentioned. It is designed to connect the lakes Onega and Bieloe Ozero (or White Lake) by means of the river Vitegra, which flows into the former. The latter lake empties itself by the Shexna into the Volga at Ribinsk. In this case two canals are required; it being necessary not only to connect the Vitegra with the river that runs into the Bieloe Ozero, but also to avoid that lake, by cutting a canal round one half of its circumference to join the feeding with the emptying stream. For the Bieloe Ozero is merely a shallow pool in the sand, of a regular oval figure; and, like most of the lakes of northern Russia, would be considered as rather a faulty spot in an improved system of navigation, though it may probably have been very useful in an incipient one.

Still further to the eastward, between Vologda and Kostroma, about sixty versts from the former town, is quarried a dark hard limestone of very good quality. Not being able to describe either the stone or the quarry from personal inspection, I mention it only to hazard the conjecture, that it may be a continuation or re-appearance of that of Borovichy*.

Here my acquaintance with the Valday chain terminates; but I believe it to be prolonged to some distance further in the same direction. This eastern portion of it is thickly wooded, and supplies a great part of the timber used in the interior of Russia, where its want is becoming daily more and more sensible, and also of that demanded by the northern export trade.

A branch of the Oural Mountains is described as projecting into the government of Vologda, with which it is possible the Valday chain may be connected on the east.

CENTRAL SALT DISTRICT.

The very extensive tract of country which I designate under this name will scarcely admit of any precise geographical boundary. I shall however endeavour to give an idea of it, by following the course of the Volga from Tver to Cazan, in a direction nearly east and west; and by giving such a

* According to Gmelin, some limestones, much of the same character as those of Borovichy, and, like it, containing a sort of coal, are found at Uryefskoy and Coudroszovo in the government of Tver. This government is celebrated for the beauty of its siliceous fossils, found in loose boulders of chert scattered over the surface of the country. As chert has been found *in situ* at Borovichy accompanying limestone, and containing fragments of the same organic remains, may not these limestones of the government of Tver, which are characterized by the same encrinites, &c. as those of Borovichy, be connected with the chert boulders, to which no place has yet been assigned, and whose organic remains, shells, &c. agree with those of the limestone of Borovichy, though not yet found in the chert of that place?

description as I am able of the country on its banks, and of some remarkable spots in the interior.

At Tver the Volga receives the Tvertza, and with it the first line of central water communication. The whole country presents nothing but a reddish sand, extremely loose, and bare of herbage: in many places the surface is furrowed in waving ridges by the action of the wind, in the same manner as the sand of the sea-shore is by that of the water. Widely different from the sand of the northern districts, it is not a poor soil; but produces rye, wheat, and flax in abundance. The Volga is here shallow in proportion to the width of its bed, which is strewed with boulders, partly primitive, partly siliceous.

At Mologa the Volga receives the river of that name, and with it the second line of central water communication. The country in every respect resembles the environs of Tver, and siliceous boulders, containing their usual organic remains, are plentiful. This is nearly the most northern point of the course of the Volga.

At Ribinsk, a handsome and flourishing town, the Volga receives the Shexna, the third and last branch of the central water communications. After these accessions of strength, the Volga visibly increases in size, and some slight difference is perceivable in the country through which it flows. The banks attain a much greater elevation, and are frequently intersected by deep and precipitous ravines, which begin to form a striking feature in the scenery, and are common throughout all this eastern part of central Russia. This may be partly owing to the nature of the red rock, which here quits its sandy character to acquire that argillaceous one, which so commonly distinguishes the salt formation in every corner of Europe where it occurs. The original sandy appearance, however, recurs at frequent intervals; but the marl usually discovers itself at the depth of a few feet. It is of a deep red colour, and often contains thin beds of the same substance, coloured greenish gray or white. This soil produces the finest pastures and most brilliant verdure found in Russia.

The next considerable town is Yaroslaf or Yarollart, capital of the government of the same name, and situated in a rich and cultivated country. In several parts of this government exist salt springs, especially in that part of it south of the Volga. In this and the neighbouring governments of Tver and Kostroma, the soil is remarkably favourable to the culture of flax, the principal manufactures for which are in the governments of Kostroma and Yaroslaf: and it is remarkable, that a similar soil produces also the finest quality of that which is exported from the northern ports, which is grown in the governments of Pscov and Novgorod.

The same rock continuing, the country improves in riches and beauty towards the town of Kostroma, which is deservedly reckoned one of the most beautiful on the Volga, as well in architecture as in situation. It would perhaps be difficult to prove that the climate of this part of Russia is at all superior to that of the provinces I have been hitherto describing; but it is certain that from the neighbourhood of Kostroma oaks are frequent, and continue to be so along the remaining course of the Volga as far as the woods continue. The scenery on the banks of the river becomes much more varied, and is enlivened by towns and villages, among which should be particularly mentioned the picturesque town of Kineshma, situated on the southern bank. In a ravine in the middle of the town, opposite the great monastery, is a sand-pit, the sand of which is partly red, like that common throughout the country, and partly white and yellow, and of that clear glassy appearance which characterizes the sand of Borovichy and of the Ishora near Petersburg. In the ravines between Kostroma and Kineshma the red marl and sand are well seen *in situ*. On the south bank, between Kineshma and Uryavetz Pavolskoy (or Uryavetz on the Volga), more commonly contracted into Uryetz, the ravines occur at every two or three versts, and at the town of Uryetz are of the depth of 150 feet, if not more. Two or three of these ravines unite just at the spot where the town is built, between their opening and the Volga. There is no water in them in summer: and in fact, they owe their origin not to the waters of the soil, but to the melting of the snows in spring. The surface of the hill is horizontal to their very edge, and the upper part of their cliffs absolutely perpendicular to the depth of thirty or forty feet, before it begins to slope towards the centre of the hollow. On the side of one part of the ravine, where the rock is no longer liable to slip, is a wood of firs; but in general the sides are perfectly bare, on account of the very regular annual decay which takes place after the thawing of the snows. The substance of the rock being very tender, yields readily to the impetuosity of the annual *débâcle*. It is the ordinary red marl, containing small calcareous concretions. In the ravines are some large boulders of ancient rocks. Near the head of one of the ravines is a large square tower, the remains of an ancient fortress, erected when this part of Russia was exposed to the incursions of the Tartars; which, together with the steep road which descends into the town, accompanied on each side by a yawning chasm, will probably be at some future period precipitated into the gulf. Some grotesque chapels, which are placed on projecting knolls round the town, are in danger of sharing the same fate.

In the government of Kostroma, salt is made in many places from brine, especially at Solyi Galich*, on the borders of the government of Vologda, where it is accompanied by gypsum.

The next considerable salt manufacture near the Volga is at Balakhna, where there are several brine-springs situated in a plain between the hills and the river. One opened in 1818 affords 13° of salt.

The plain extends from Balakhna to the mouth of the Oca, the hills turning off abruptly to the south. The ground is low and marshy, being often flooded by the two rivers. Some part of this plain is probably of alluvial formation; but how much of it owes its existence to recent depositions would be difficult to determine.

Opposite to this plain, which is triangular (being bounded by the two rivers and the ridge of hills above mentioned, on the left of the Oca), stands the town of Nishney Novgorod, on the point of a triangular elevation, which fills the angle on the right of the mouth of the Oca, as the plain just described fills up the left. The hill is extremely steep, rising almost from the water's edge: the apex, on which is placed the ancient Kreml or fortress, is stated by the engineers to be above 400 feet in height above the river. This high ground is intersected by numerous ravines of great depth, even in the middle of the town. One of these extends so far into the body of the hill, as nearly to join one that begins on the other side of the town, and opens to the valley of a small river flowing to the eastward. This stream does not join the Volga for ten miles below the town.

But the most remarkable chasms are to be seen on the Oca, just above the town, under the walls of the convent which stands between the Moscow road and the river. They cannot be less than 350 feet in depth; but show nothing but horizontal strata of red and white marl. Still higher up the river, near the fifth verst on the same road, is a beautiful view over the whole valley of the Oca: a little to the right of this spot, a path leads to the head of a romantic dell, which descends towards the river, and which far surpasses in picturesque beauty any thing in the neighbourhood of Nishney Novgorod. The path winds down among broken hills, here and there exposing perpendicular cliffs of red rock-marl, which, when seen between the tufted woods of oak and ash in which they are embosomed, and through which is caught from time to time a view of the winding Oca studded with sails, cannot fail to recall the smiling landscapes of the western counties of England. In the deepest part of the

* Solyé Galich, or Sol Galitzkoy.

valley a stream makes its way down to the river, which it enters near the salt magazines *.

The Volga too, below the town, has no less claim to notice than the Oca. About two versts from the fortress, on the left side of the road to Cazan, are seen ravines and chasms of the same nature as those so often described. But a little further on, the lofty bank of the Volga becomes wooded and cultivated. On a knoll considerably lower than these banks, but yet raised high above the river, is placed the monastery of Pechersk, and not far from it a large village of the same name. Beyond it is seen, in a situation somewhat similar, the white steeple of the church of Podnolyé, another considerable village, which, as well as Pechersk, is built close to the water's edge. The roads down to these villages, winding among the large trees and orchards with which they are surrounded, are no less remarkable for beauty of scenery than for some geological circumstances which may there be examined. We here see for the first time beds of pale red sandstone alternating with the marl. The colour of this sandstone sometimes varies to a dusky green, and is marked by irregular concretions and a sort of globular structure, like those of Borovichy and the Poporca. The red variety sometimes presents a singular appearance, when, with the fracture and aspect of a very ill made brick, it discovers, on breaking, a number of flattened cells or cavities, in which are loose concretions of marl, usually of some shade of red, which easily fall out of their receptacles. At the bottom of the cliff along the shore is seen a thick bed of a remarkably hard and compact tuf, the cavities of which are often lined with brown sulphate of lime, deposited stalactitically; it sometimes nearly resembles that found among the solid alabasters, and is capable of taking a fine polish. Fresh-water shells are found in this tuf, though rarely. A similar formation exists on the Oca near the salt magazine.

From the summit of these heights may sometimes be seen a phenomenon similar to what has been observed in other places. The blue waters of the Volga, on receiving those of the Oca, which are by no means of an equal degree of purity, are seen to flow uniformly along the left side of the channel; while the other stream on the contrary keeps as regularly along the right. From their point of junction, the difference of colour is too striking to be overlooked by the most casual observer; and it appears but little abated where they pass out of sight. The explanation of the phenomenon is simply this:—The Volga above

* These magazines are not stored with the salt of the neighbouring districts, but with that of the Steppes of the south-eastern parts of Russia, which is supplied at a cheaper rate for the consumption of the interior.

Nishney Novgorod, as well as the greatest part of its tributary streams, (which it is remarkable are much more numerous and considerable on the north side than on the south,) flows through a tract of country almost universally covered with sand. The Oca on the contrary flows through a country of rich red marl, in its strongest and most argillaceous form: neither of the two rivers being sufficiently rapid to disturb immediately the new body of water with which it comes in contact, the effect above described is naturally produced.

The situation of Nishney Novgorod at the confluence of the two principal rivers of central Russia, and which thus connect the two richest and most populous districts of the empire, the provinces immediately south of Moscow and those on the upper Volga, is singularly adapted for commerce, independent of its more distant connexions. Here naturally centres not only the greatest internal trade of the empire, but by the lines of navigation I have before detailed, this town has a three-fold communication with the provinces of the north and with the Baltic; and, by means of the Oca and Moskva, with Moscow itself. The Kama, which meets the Volga a little lower down, brings all the produce of Siberia, the iron and copper of the Ourals, the gold and silver of Kolyvan, and the beryls, amethysts, and topazes of Nerchinsk. The trade with China is also carried on by means of this river. The commerce of central Asia, to which we owe the introduction or the recovery of the true Turquoise or Calaïte*, as well as that of the south of Russia and Persia, comes partly from Astracan and the Caspian Sea by the navigation of the lower Volga, partly by caravans, which arrive on the banks of that river in different parts of its course. The supply of European commodities is furnished chiefly from Petersburg. These commercial advantages, added to the circumstance of its being placed in the centre of one of the most fertile districts in Russia†, in most of which particulars it has greatly the advantage

* By far the clearest and most accurate account of this stone, and of the difference between it and the coloured bones which have been mistaken for it, (and for which it has itself been also mistaken,) is to be found in Professor Fischer's treatise on this subject.—Moscow. 1818.

† When the science of geology shall have made men thoroughly acquainted with the history of the substrata, their attention will probably be directed to the nature and formation of the vegetable soils which cover them; nor will this be the least useful object of their labours. The government of N. Novgorod contains the three soils most common in Russia; the sand, red marl, and black earth. The sand found in the western parts is the poorest, the other two are remarkably fertile. The red marl is chiefly found along the Volga and on the northern side of the government. Besides corn, it produces the finest grass and oaks, as may be seen in one of the finest forests of Russia, near Vasil Soursk, entirely composed of oaks planted by Peter the Great at a time when wood was much more plentiful than it is at present. The black earth makes fine corn land, but seems less adapted to the growth of oak timber, or for fine herbage,

both over Petersburg and Moscow, are believed to have inspired Peter the Great with the idea of ultimately fixing in this spot the capital of the empire. As this design was neglected after his death, this important situation had been overlooked till within a few years past, when the great bazaars and buildings at Makarief having been destroyed by fire, the government determined on removing the seat of the fair annually held there, to Nishney Novgorod; both on account of its situation, and from its being nearly an hundred versts higher up the Volga than the original place of Makarief; while the additional journey to the eastern trade is insignificant.

In pursuance of this object, a new and magnificent bazaar is building on a vast scale upon the plain, on the left bank of the Oca, opposite the town of Nishney Novgorod, to which it is joined by a light and elegant bridge of boats. This plain, however, being purely alluvial, or, in other words, a sort of Delta formed by the Oca, is subject to regular floods from the waters of both rivers. It happens, rather unfortunately, that the Volga and its affluents coming from the north, while the Oca flows directly from the south, the difference of climate between the tracts of country that are drained by these two rivers is sufficiently great to cause a difference in the time of their respective inundations. Thus the ice on the upper part of the Oca, and the snows of the country on its banks, break up sometimes a month earlier than those of the Volga and other northern rivers; and at the time when the waters of the former river would naturally subside, the flood is prolonged, increased, or renewed, by the melting of the ice on the former. In addition to these difficulties, the action of the two rivers on their banks presents an evil of considerable magnitude. At their confluence the two rivers are describing in their course the segment of a very large circle, the concavity of which is, in each case, on their right bank; on which side of course the destroying action takes place, whilst the left bank of each river becomes the deposit of whatever they leave behind. Now the right bank of the Oca is lofty and precipitous, and though it may require some ages for the action of the river to do material damage to the town, yet it has barely left room for one narrow street at the foot of the hill, which is regularly under water every year. But the right bank of the Volga, on the other hand, is a low and sandy accumulation of alluvial origin, being in fact only one side of that sort of Delta which

than the other, being overrun with wormwood. It is said to extend from the Kama to the Dniestr, and in all the governments between the two rivers forms a rich and productive soil. I have followed it 150 versts on each side the Volga, and found it covering red marl sand, white marl, in short every kind of substratum, with one uniform coating of black mould, from a foot to three feet in depth, and spread over hill and dale like a regular but unconformable bed.

the Oca has deposited at its mouth. Of this, large portions are carried away annually by the current, which throws it upon the left bank, where it has formed an extensive sandy plain, intersected by small branches of the river. The islands which they surround are covered with low brushwood, and are still flooded annually. This plain therefore is not cultivated; and as the land behind has but little elevation, it is not immediately perceived that it is as fertile and as much inhabited as the high grounds on the south bank of the river. The Oca in like manner deposits on its left bank all that it brings down from the right: so that this alluvial triangle is annually gaining on one side, while it is losing on the other; a considerable deposit being left also on the surface of the plain itself. It has been necessary however to raise the surface many feet, in order to keep the water out of the bazaar; the necessary quantity of earth being supplied from the excavation of a canal which is intended to surround the whole; and a protection is also required against the ravages on the side of the Volga. It may be asked why this weak and perishable angle between the two rivers was chosen, in preference to the more solid one on the opposite bank? The fact is, that there is not room at the foot of the hill to place any thing like requisite buildings for the merchandise accumulated at the fair: also, that the little space there is, is annually lessened or endangered by the action of the Volga on the north, and of the Oca on the west,—both rivers here conspiring to destroy the hill. On the summit of the hill the ground is too uneven to admit of regular buildings of such a size, without being endangered by the ravines, whose banks are nearly as insecure as those of the river; besides the labour and risk of bringing heavy goods up a steep of four hundred feet in height, which must all descend again to be trans-shipped. The only good situation is already occupied by the Kreml, which completely covers the lofty angle between the Volga and Oca.

The stone used in the new constructions, is partly the hard tuf of Pechersk, which is blasted by gunpowder,—a method newly introduced there; a white limestone from the upper Oca, which will hereafter be mentioned; and in part a red sandstone, containing numerous glassy concretions of sulphate of lime, which is quarried at Novinski, about sixteen versts up the Oca. This sandstone, though not much resembling the young red sandstone of England, is probably allied to it, as occurring in company with gypsum, interstratified with a saline red marl. There is also at Novinski another species of white limestone, much intersected with small veins of glassy gypsum, but containing shells, which are in general of rare occurrence in any form of sulphate of lime. Specimens are in the collection of the Geological Society, and in the Museum at Oxford.

Among the greatest natural curiosities of the government of Nishney Novgorod, must unquestionably be reckoned the rocks and cavern Barnoucova. They are situated near the western extremity of a ridge of hills that accompany the northern bank of the river Piana, which flowing first westward doubles the end of these hills, and then runs eastward, by the town of Cergach, till it reaches the Volga.

A round hill, covered with a wood of oaks to the very summit, is at this place hollowed on one side into a natural amphitheatre, accessible only by a rugged path, which follows a small stream issuing from a narrow opening between the hills. On pursuing this stream into the recess from which it flows, some lofty perpendicular rocks appear above the wood on the right hand; and a few steps further, on turning a sudden corner, the dell widens a little, but is suddenly barred across its upper end by a precipitous cliff of considerable height and snowy whiteness. A small lake lies in the hollow, fringed with oaks, and which has an outlet by the stream which accompanies the path. The white cliff rises abruptly from behind the lake, and a woody eminence above terminates the scene. But the beauty and repose which characterize this sequestered spot, are not the only features which distinguish it. On arriving at the foot of the cliff, it is discovered to be of the purest alabaster; and on passing the tangled brushwood which conceals it, is seen the mouth of a cavern formed in a rock, of which it is no exaggeration to say that it resembles the driven snow; for to no other object in nature does it bear any resemblance. On descending towards the mouth of this cave, although yet at a distance of several feet from it, a sudden and remarkable sensation of chill is strongly experienced: it seems at the moment as if the rock, which has all the appearance of snow, had also its coldness; and in ascending the rocks on either side, the return to perfect warmth is felt instantly on rising above the level of the cave. The interior soon contracts*, and is, as might be supposed, intensely cold; a quality remarkable even during the hottest weather. On the right hand, the tops of many of the flatter or larger masses which rise above the trees, not only glitter in the sun like drifts of snow, but the purity of their colour, their powdery texture, and even their furrowed surfaces, which are channelled and waved as if by the action of the wind, contribute to deceive the observer, and produce the most perfect resemblance. The rock is indistinctly stratified in large beds, and contains starry crystallizations of

* Pallas visited Barnoucova in 1768. For a minute description of the cavern, which makes it needless for me to say more upon this subject, see his Travels, vol. i.

selenite *. The neighbouring country is all red rock marl, in which the alabaster forms subordinate beds.

About eleven versts higher up the river Piana, is the village of Tzaitska, situated on the side of the ridge of hills that extends from Barnoucova. An ancient wooden church in the most grotesque style of Russian architecture stands on a bank, the structure of which is laid open in a cliff just below it. Regular horizontal strata of red marl are discovered alternating with grey and white beds, of the same nature as at Nishney Novgorod; and as at that place, the grey beds contain a substance which has been taken for the mineral called rock-leather †, but which on examination proves to be a coriaceous form of fibrous gypsum. It is interposed in continuous layers between the beds of marl, and might be pulled out with care in sheets of several square feet, as it is very tough. I have not found it anywhere in so perfect a state as at Troitska, though it occurs more or less in all the marls of this district. The only difference between the appearance of the cliff at Troitska and those at Nishney, is, that in the latter instance small beds of sandstone occur, which are wanting in the former. The vegetable soil which covers the cliffs on the Oca, is of a deep red, like the rock itself; while at Troitska it is a thick bed of jet black mould, although the rock below is exactly similar in colour and nature to that of Nishney.

The red marl continues to be seen along the banks of the Volga, and prevails in the governments of Cazan and Simbirsk: the most distant locality of it, that I can mention with certainty, is at Tetushy, which is built on the summit

* Where the beds of alabaster pass into the red marl, they form a pale-coloured compact limestone, containing selenite. This would naturally be the bed in which to look for gypseous shells like those of Novinski, but I was not lucky enough to discover any decided trace of organic remains.

† See Mém. de l'Université de Moscou, p. 253.—The mineral which Dr. Pansner is there said to have brought from Nishney Novgorod, is identical with that of Troitska here described, and is found in similar beds *in situ* in the red marl. It is quite evident that this cannot be an alluvial product, or have come out of a hill of alluvium (400 feet in height). That which is described by Professor Fischer, in a subsequent part of the same paper, as found near Mourom, is identical with what will be described hereafter under the head of Vixa; except that instead of occurring in ironstone, it is in a calcareous concretion like what I have found at Myavetz Pavolskoy; this concretion may have been in alluvial soil.

Having seen the specimens in both cases, in the possession of those who found them, and having visited the localities and found the minerals myself *in situ*, there and in other parts of the same district, I am enabled to speak positively upon this subject.

Coriaceous gypsum occurs also in the red marl of Devonshire.

of a high cliff of marl exactly resembling that of Nishney, except that its beds are undulating rather than horizontal. On the opposite bank of the Volga stand the ruins of Bolgary, the ancient capital of the Tartars; as is attested by an inscription in Tartar, and by the coins of silver and copper bearing the names of their princes in Mongol, which are frequently dug up there with various other pieces of antiquity. The remains of several baths and minarets are remarkable as being entirely built of stone, a sort of masonry hardly to be seen in Russia. The stone seems partly to come from the same beds which are used for foundations at Cazan, partly to be a species of tuf. No quarries are visible near the ruins. The Arabic, Armenian, and Tartar inscriptions (many of the Arabic, in Cufic characters) are well preserved and have been given by Lepekhin. These remains of antiquity were first ordered to be preserved by Peter the Great. Over the door of one of the buildings are some Arabesque figures and chain patterns carved in a sandy stone, probably from a bed alternating with the marl, which have resisted the ravages of time better than most of the external parts of the buildings. The hill on which they stand is of a loose sandy rock, probably a form of the red ground. The black soil which covers it is clothed with the yellow flowers of the Scabiosa Tatarica, and in the peasants' gardens produces magnificent hops, which in August were covered with bunches of three inches and a quarter in length, and broad in proportion; it bears also rich crops of corn and sunflowers.

The same sand rock extends northward to Cazan, and is seen on the south at Simbirsk. At the latter place, the upper part of the hills on the Volga contains great quantities of very white marl (kreide mergel of Pallas), which appears also at Tagay west of Simbirsk, and is seen along the brow of an escarpment of bare downs for several miles. At Chircovo, the ridge between the rivers Sara and Soura is composed of a variegated sandy clay, sparkling with selenites. At Ardatof (Simb.) the same strata appear, either marly or sandy, as at Nishney.

It will be necessary to mention here the limestone of Cazan, for although it has peculiar characters, yet it appears to belong to this formation. It is of a greyish yellow colour, usually very distinctly oolitic, and at the same time much harder and more compact than those rocks which form the oolite series in England. It contains terebratulites, and long stalks which appear to be of organic origin, although a regular termination is wanting at either end. It contains small milk-white concretions of radiated quartz. The only rock I have seen like it, is a hard oolite in Podolia *.

* This limestone appears in beds jutting through the sand, on the side of the hill going up to

Opposite to Cazan, near the town of Iviashsk, commences a high ridge of hills, which run due south between the Volga and Sviaga as far as Simbirsk. Thence it skirts the whole right bank of the Volga to near Sarepta, and forms the eastern part of the High Steppe of Pallas. The northern part is still wooded; but the remainder is more like the downs of the south and west of England than anything I have seen on the continent. The greatest part of what Pallas described in 1769 as open Steppe, is now brought into cultivation, some of the hills being left for cattle as in this country.

In the Ouslonsky hills, that part of the chain immediately opposite Cazan, the cliffs on the right bank of the Volga show the usual alternations of red and white marl. There are also some beds of a limestone whiter than that of Cazan, and somewhat more like the white limestone of the interior; which is likewise quarried and brought to Cazan. It may be of the same kind with the white magnesian limestone of Roche Abbey near Doncaster.

I will mention here another deposit apparently not connected with the salt formation, but which appears in several patches along the central part of Russia. It is a black clay, containing pyrites and green sand in abundance, and usually full of organic remains. Its most eastern locality that I have seen, is at Simbirsk*, where it occurs at the foot of the hill under the town, on the bank of the Volga; it is probably continued on the other bank; and it appears also at Polymnia, a few versts higher up the river. It is well seen below the church nearest to the river, where large slabs containing ammonites of great size, beautifully iridescent, are lying at the surface of the ground. There are also seen in it mytilites, and a few large and coarse septaria. The apparent situation of this rock is *under* the sand.

A similar rock is found also at Mourzikha on the Soura near Courmish, where large multilocular shells, of a nature intermediate between the ammonite and nautilite (resembling the well-known fossil of Kelloway in Wiltshire), are frequent; they are covered with a beautiful pearly crust, and are sometimes carried down by the floods into the Volga at Vasil-Soursk. When cut, the interior of these shells is usually found in a delicate state of preservation†.

the Kreml or fortress, but is not distinctly seen on the other side in the cliffs on the Cazanka. Specimens of it are in the Museum at Oxford.

* The view from the hill of Simbirsk (Plate 1. fig. 3.) shows the relative situation of the white marl, sand, and black clay. The rocks in the distance are the white central limestone, forming the High Steppe of Pallas, which near Cinghylëy rises into the high hills which border the Reach of Samara.

† These appear to fall under the genus which Parkinson proposes to call Ammonautilus;—Organic Remains, vol. iii. p. 108.—They certainly are the same which Parkinson mentions at p. 140,

A deposit of the same kind has been met with at Vixa at a considerable depth, but the specimens I saw there may have belonged to rolled masses.

A black clay is seen on the left bank of the Oca at Mourom, also beneath the sand; but as it contains no organic remains, it is not yet identified with any other bed.

It is very common in some parts of the neighbourhood of Moscow, where it also seems to lie under the sand of that country, and may be well examined at Petrovsky and at Kharashova. It there contains pyritical ammonites, black siliceous wood, and belemnites*. Some specimens of it include dentalia, sometimes covered with pyrites, sometimes imbedded in masses of black chert.

About twenty-four versts west of Moscow, near the village of Tatarki, is quarried a white siliceous sandstone, used at Moscow for foundations, and sent to distant parts of the country for millstones; but which are inferior to those of Voronesh. The Tatarki stone is often of a pinkish hue, and lies in large slabs with irregularly waved surfaces.

Central Mining District.

This tract includes parts of the governments of Nishney Novgorod, Vladimir, Tambof, Rezan, Toula, and Calouga; extending from a little above Mourom on the Oca, to near the town of Calouga. It is in general a very poor sandy district†, and probably belongs to the red-marl formation, although its connexions are not very distinct. Along it are situated several extensive iron works‡; for in general the iron is manufactured where the ore is raised. These supply the principal consumption of that metal in the interior of Russia. One of the most considerable is the establishment at Vixa and its dependencies, in the forest of Mourom, belonging to Mr. Bataskoff.

as being found near the river Moscva (Russ. Moscva Reca), about a league from Moscow,—probably at the places hereafter to be noticed, as showing the black clay.

* Pallas mentions a similar rock, as a probable indication of coal at Cashponr, lying under a hill of white marl like that of Simbirsk and Tagay, but mentions no sand between them.

† It is nevertheless more fertile than the sand of Petersburg, since, without manure, it lies fallow only every third year, and gives a return of eight for one. When properly treated, it bears tolerable crops, especially of lucerne, a plant which has almost naturalized itself where it has been introduced. Among the surface gravel, are rolled pieces of granite, limestone, and chert.

‡ The Crown works of Toula employ exclusively Siberian iron: this is the principal manufactory of arms in Russia. The manufactory at Calouga formerly attempted the finer kinds of cutlery, but failed.

The forest of Mourom* is a tract of more than fifty versts in length, which stretches along the right bank of the Oca above Mourom: its sandy soil and gloomy appearance resemble more the forests of Carelia, than those of the central governments in general. At the depth of sixty feet below the surface is found a series of beds of ironstone of variable quality; some of the beds are dark red and argillaceous; others are mere layers of large concretions, the outer crust of which is an argillaceous rusty earth, while the centre is solid, and of an ash-grey colour: there are also regular strata of pale yellowish-brown coloured ironstone, which is the ore principally worked. Of the two latter varieties, the lightest coloured ores produce the most iron. The mines, if they may be so called, are in several parts of the forest; the principal about two or three versts from the ferry over the Oca, on the road from Vixa to Mourom. Here the whole surface of the ground appears as if covered by large mole-hills: they are the heaps with which the old pits are covered up. The present system of working is, to sink a shaft, as if for a well, till it meets the bed of ore, and to raise what lies within the circumference, and perhaps a little more all round, and then to close the shaft, and sink another as near to the old one as convenient. In this manner the whole ground is perforated with small holes as near together as they can be placed: no gallery is driven, and all the ore is got out by a shaft immediately above the spot where it lies. The reasons given for this apparently expensive mode of working are, that the ore lying so near the surface, it is little more expensive to arrive at it through a soft bed of sand, in which it is easy to sink shafts, than to drive galleries, for which much timber and machinery might be necessary; since the sand, from its loose texture, would require a vast structure below to support it: yet there is a superabundance of timber in the immediate neighbourhood.

* The history of the foundation and progress of the iron works at Vixa is not devoid of interest. About fifty years since, the present owner, who with his brother had been engaged in the iron works at Toula, and who possessed a certain knowledge of this part of the country, imagined that the ironstone of the government of Toula was likely to extend into the Forest of Mourom. He followed therefore the course of the Oca; and finding pieces of iron ore on the banks of the river, was induced to try whether it existed *in situ* in the neighbourhood. He actually found that its strata were at an inconsiderable depth below the surface on the right bank. This was in the Forest of Mourom, then almost uninhabited, except by banditti, which were then in sufficient force to oblige him to take an escort of Cossacks in the researches which he made for ore. Being satisfied of the quality of what he found, he bought, at an extremely low rate, a vast parcel of the forest, then Crown land; and he now possesses, in the midst of the barren wilderness,—besides a large country-house, with English and Italian gardens, a theatre, a bazaar, and a market,—eleven separate iron works, at from four to twenty versts distance, handsome churches, villages, and 30,000 inhabitants, as his share in the adventure.

In some parts of the district are chalybeate, and in others sulphureous springs, at which buildings are erected as hospitals for the establishment. In digging for these were found the fragments of the black rock with ammonites, and also of the siliceous rocks containing shells.

Central Limestone District.

There extends across the middle of Russia a tract of limestone of a very well-defined character. It is generally of a very pure white, completely filled with broken encrinites, large terebratulites, caryophyllites, pectinites, and the exuviæ of other marine animals. Its extent may be taken from the reach of Samara on the Volga to the country between Smolensk and Moscow: it is easily recognised under the characters above stated. Near Moscow it is quarried at Machcova, where the earthy varieties nearly resemble chalk, and have sometimes a pale yellow colour. There are also in that part of Russia two species of marble, which should be noticed here, as they are probably members of the same formation. One is the yellow marble of Serponkhof and Colomna, both on the Oca, near which places it is quarried, to be used in Moscow for ornamental purposes. It contains fragments of encrini, and a very large species of terebratulite with a spiral hinge, found also in the mountain lime of Derbyshire. It is very frequently covered with dendrites. The other marble is found near Aleshina, between Moscow and Colomna, and is of a dull reddish-brown colour, and is sometimes used for tables. It contains large specimens of the Anomites productus, like those of Borovichy*.

This white limestone† occurs also in great quantity on that part of the Oca above Mourom, where the governments of Nishney Novgorod and Tambof join those of Vladimir and Rezan. At Ounsha near Yelatom, one of the iron works dependent on that of Vixa, and at Gelat in the same neighbourhood, it is quarried for the use of the smelting-houses. It contains its usual

* A mineral called Ratofkite is found lining the surface of siliceous layers in marl, on the river Ratofka near Moscow. Professor Fischer has published an account of it: *Mém. de l'Université de Moscou*, tom. 5.

† A limestone with flints is stated by Bray to occur on the Düna, where it enters Livonia; but it is doubtful whether it is a prolongation of the limestone of the Valday, or of that of Central Russia.

A white entrochal limestone occurs in Scania, but its exact geological relations are not known; it much resembles that of Machcova.

fossils in abundance and good preservation. Further eastward it appears in the south part of the government of Simbirsk, and it is seen on the banks of the Volga for a great distance both above and below the town of Cinghylěy: it forms the lofty ridge which diverts the course of the river between Stairopol and Syzran, and is called by the name of the Markvashky and Shigoulefsky Hills. These are the highest banks of the Volga. The hill called Tzaref Kourgan, or King's Barrow, at the mouth of the Sok near Samara, is not artificial, but is composed of strata of grey limestone, with minute madrepores, which in shape and size resemble grains of wheat*.

The limestone at Sernoi Gorodok contains sulphur mines, no longer worked; they are in the hills called Sokoly Gory. The banks of the Volga, in what is called the reach of Samaraarc, are wild, and possess an interesting character. I must refer to Pallas as an authority for the vultures, chalk, gypsum and sulphur, and other wonders of the place.

Oural Mountains.

This primitive chain, running from the Icy Sea to the steppe north of the Caspian Sea, forms the natural boundary between Asiatic and European Russia: and I must include in this district a certain portion of country on each side the chain †.

A rich and extensive tract of red marl, salt, and gypsum, stretches down the course of the Kama, and is probably connected on the south with the salt district of the Volga, and on the north with that of Vologda. The principal salt works are in the neighbourhood of Solikamsk; and the alabaster grottos of Koungour, in the government of Perm, exceed in size and magnificence the cave of Barnoucova. At intervals along this line appear springs of naphtha, every where considered as a sign of coal, which however has only as yet been found on the Ousva, nine versts from Alexandrovsk, where it occurs with a rich argillaceous ironstone, manufactured at the latter place, the establishment of Mr. Vscvoloshsky.

But on both sides of this salt country is a vast tract of what is commonly called copper sand, which extends through a great part of the governments of Viatka, Perm and Oufa, and completely skirts the south and west sides of the

* A specimen is in the Museum at Oxford.

† A secondary tract appears on the side of the Oural Mountains, forming the western or low division of Siberia; but I am not able to state with certainty whether its rocks resemble the formations on the European side.

Oural mountains. This sand is of a dull red or green, and is commonly worked for copper. It contains fossil wood impregnated with copper, and what are supposed to be casts of cacti, resembling the fossil vegetables of the English coal formation. It sometimes occurs also in the state of a conglomerate.

In the neighbourhood of Orenburg, where this copper sand is extensively worked, is, according to Falk, a limestone which contains shells, and lies immediately on the granite of the Obschey Sirt, the southern projection of the Oural chain. (See Falk, vol. i. p. 182.) The alabaster rock seems to belong to the salt formation; which, as will be seen, forms islands in the centre of the desert steppe. A salt district, full of saline lakes, exists on the south-east corner of the Ourals, and seems to connect Siberia with European Russia and the steppe of the Kirghis.

There seems to be no continuous primitive ridge connecting the Oural and Altay mountains. Insulated granitic hills, surrounded by the salt district and partially wooded, are described as existing near the frontier. The mountains in the steppe opposite Orenburg and Orsk, resemble those within the Russian frontier: they contain copper and salt, which latter is worked by the Russians under protection of a fort at Iletsk.

The Oural chain consists of various primitive rocks, remarkable for being finely and distinctly characterized. Primitive marble exists in many places, but is now little worked; and the southern and eastern parts are celebrated for the beauty of their ornamental jaspers, which occur in large rock masses. The iron and copper mines, and other mineral treasures of the Ourals, are too well known, and have been too often described, to require mention in this place.

SOUTHERN RUSSIA.

The secondary rocks, of which I cannot give any detail, are continued across the whole of this country till we arrive at the primitive steppe. Good coal has been found near Toula, where it is worked; but the quantity is so small, and the difficulty of working it beneath a loose and half-liquid bed of quicksand is so great, that it seems unlikely to be of much utility. Coal has also been worked at Bakhmout, in the government of Katerinoslaf, where it is accompanied by hills of schist, which border the Donetz, as described by Pallas in his Second Voyage.

Steppes*.

Primitive Steppe.—The first part of the steppe district with the geological features of which I am in some degree acquainted, is that primitive tract which stretches in a direction E.S.E. from the upper part of the river Bug to the Berda. It occasions the rapids of the Dniepr, and passing to the south along the Bug, terminates within a short distance of the Black Sea. The rock in this tract is a coarse-grained granite, containing garnets, but sometimes passing into trap or syenite. It forms a level country, intersected by deep ravines, and is without woods. In Volhynia, near the borders of Gallicia, it affords a fine white earthy felspar, fit for making porcelain. It occurs at Croupetz on the road to Lemberg.

Calcareous Steppe.—A series of calcareous rocks accompanies the southern border of the primitive steppe, following the line of the Dniestr and the coasts of the Black Sea. Some large-grained oolites appear near the frontier of Gallicia, as also between the Bug and Dniestr near Tomaspol, where they are very hard and compact; and again, of a very fine grain, between Bender and Odessa. A shelly limestone, much resembling those of Purbeck and Portland, occupies a large tract between the two rivers before named.

The only new formation is that of bitumen in the peninsula of Kerch, at the entrance of the sea of Azof, which appears also in the opposite peninsula of Taman, and at the other end of the Caucasian chain, in the promontory of Bacou, on the Caspian Sea. Limestones of secondary formation form a high steppe, in the intermediate space, around the northern edge of the Caucasus, and compose the first ridge of elevated land which appears south of the steppe of the Courna. It appears that the bituminous formation of Bacou, in the peninsula of Abkharon, is comprehended in a ridge of argillaceous shale,

* The etymology of the word *Steppe* is a disputed point, even among the Russians; it may possibly be of Tartar origin. The word steppe is applied generally to any waste land whatever, provided it is not covered with forests. Thus we hear of the high, the low, the rich, the poor, the salt, the sandy, the icy, the stony, and other steppes: districts differing in almost every character, except in that of being desert. The high steppe is like the Downs of England, but without their fine herbage, being much covered with wormwood. The low steppe, formed by the sinking of the waters of the Euxine, is *sui generis*. Some of the small grassy valleys among the Ourals are called steppes: but the term is applied to no mountainous country within the territory of Russia. Part however of what is generally called the steppe of the Kirghis is mountainous. Some of the tracts lately reclaimed from the waste are still, incorrectly, known by their former name of steppes. In the Russian language, the desert of Africa is called the *Africansky step.*

which forms the bulk of the country of Shirvan. The hills of Dagestan and Shirvan nearest the sea on the north of Bacou, are composed of a shelly limestone. The bituminous formation re-appears in the Isles of Naphtha, on the eastern shore of the Caspian, and, it is said, also in Georgia.

Salt Steppe.—The most remarkable of all the steppes is that which, lying at an extremely low and generally uniform level, extends between the Black Sea and the Caspian, and of which Pallas has partly traced the ancient boundaries. It is marked by an extreme want of fresh water, and is covered with sand and recent shells, such as are now found in the neighbouring seas. The lakes and pools which it contains are mostly salt *, and the scanty vegetation of the steppe consists of such plants only as are found with us on the sea-coast, or which are of a like nature. The rock under the superficial sand is a hard clay, sometimes left bare. It may easily be imagined that this district is of an extreme sterility, and is consequently scarcely inhabited.

The origin of this steppe is usually attributed to a change of level in the waters of the Black Sea, which, having burst a passage through the straits of Constantinople, left dry the shallow tract between it and the Caspian. The extent which this sea is supposed to have occupied formerly is loosely traced upon the map; according to which there must formerly have been either two inland seas, separated by land in the neighbourhood of the Bosphorus, or the Mediterranean must have extended to the interior of Asia, as far as the low steppe continues; and in that case its eastern shore would have been the high land which, in the steppe of the Kirghis, connects the Altay with the Himalaya mountains. Many considerable islands and peninsulas would have thus been formed, such as the Crimea †, Kharizm, the Beshtan, &c.: for the bed of a strait is said to be traced across the isthmus of Perecop, including the steppe of the Dniepr on the north, and a part of that of the Crimea on the south; the Lake Aral would have been joined by narrow seas with the Caspian on the north-west, and perhaps also on the south-west. And among the smaller islands would have been those insulated hills, which now rise in the steppe between the Volga and Oural rivers, and which consist of alternating strata of limestone, and red and yellow sand, and clay, with salt, gyps, and alabaster, like those which accompany the salt formation in the south of Russia.

* The salt contained in the ground is frequently said to form an efflorescence on the surface resembling hoar-frost. Salt rain also is said to fall in the neighbourhood of the Caspian Sea, although its waters are much less salt than those of the British Channel, where that sort of rain is not known.

† See Pliny, Hist. Nat. lib. 4.

Of these the rock or mount Bogdo is the most remarkable, being eight versts round and nearly five hundred feet high (in part perpendicular) above the plain. The hills of Chapchachy *, Minggan, Khonggor, Arsagar †, and that of Inderskoy ‡, beyond the Oural river, are of a similar character, and generally contain salt lakes: Yelton and other considerable salt lakes occur at a distance from them.

Although this theory of an extension of the Mediterranean Sea may be on the whole correct, it would obviously be vain to attempt any detailed account of the former condition of this tract of country, till accurate levels and surveys shall have been taken of the entire steppe §. The traditionary idea among the ancients that there was a communication between the two seas by means of the river Phasis, though false in itself, may have been founded on the existence of a strait at no greater distance from the Phasis than the Manych, which is the most likely situation for it ‖. Indeed the communication between the two seas could never have been much more than a strait; and the term river would hardly be an objection to this idea. The actual enlargement of the Caspian towards the north, and its communication at that end with the lake Aral, formerly much larger, may also account in some degree for the ancient notion of its opening into a northern ocean; especially if we consider that in the oriental geography of the ancients, the north-east seems commonly to have been mistaken for the north, and thus to have occasioned the erroneous disposition of the Caspian in their maps with regard to the cardinal points.

The Caucasus is a primitive chain, containing in many places columnar trap **. The older secondary rocks on its northern border, are a continuation of those which form the highest mountains on the south coast of the Crimea, where primitive rocks are wholly wanting. These mountains are principally composed of slate, with a conglomerate, and older limestones, in which the hard oolite is apparently insulated. Behind these are chalk and flint, with pyritical

* Gmelin, vol. ii. p. 8; also Pallas 1st Voy. vol. iii. p. 667; and 2d Voy. chap. 7.

† Pallas 2d Voyage. ‡ Pallas 1st Voyage.

§ The Survey by Engelhardt and Parrot, from the mouth of Couban to that of the Terek, crosses an interesting line of country, and makes the Caspian Sea to lie in a hollow; its level being, according to their measurement, 54.2 toises lower than that of the Black Sea. This sufficiently proves the steppe, though comparatively even, to be by no means level.

‖ See Strabo; and Pliny, who speaks more directly to the point. Hist. Nat. lib. vi.

** See Reineggs' Travels in the Caucasus, in German.—It is much to be regretted that no translation exists of the greater part of the travels in Russia. Pallas alone of the older travellers has appeared in English, and with Gmelin and Biberstein has been translated into French; but Reineggs, Krasheninikof, Güldenstädt, Falk, Lipekhin, Renovanz, Georgi, Hermann, Engelhardt, and Parrot, are still to be read only in German or Russian.

balls, exactly as is seen in England and France: chalk is seen also on the Dniestr near Moghilef*, and on the Gallician frontier between Brody and Radzivilof; the sandstone of Lemberg intervening between the chalk and the Carpathian mountains. The most southern part of this secondary tract is composed of a soft yellow shelly limestone, extending along the shore of the Black Sea from the heights of the Dniestr and Odessa, across the mouth of the Bug and the Dniepr towards Cherson: and similar strata, especially the oolites, are found in Moldavia and Valachia. The country, though bare of wood, is fertile.

Secondary strata, which I suspect to be partly a continuation of these limestones, form the High Steppe of Pallas, along the Don and lower Volga, and probably stretch further north.

The greatest part of the interior of the Crimea, as described by Pallas, Engelhardt, and Parrot, appears to consist of strata of similar character to those above mentioned; but gradually rising towards the mountains of the south. These strata form what is called the steppe of the Crimea, and are continued on the eastern side of the Sea of Azof, along the northern edge of the Caucasus towards the Caspian. The descriptions and maps of the Crimea represent it as affording a most perfect example of a regular series of diluvian escarpments.

* In the ravines communicating with the Dniestr near Moghilef, is found siliceous wood, in considerable quantity: it much resembles that of Portland. Siliceous wood resembling that of the Palm tree has been found near Tomaspol.

II.—*Remarks on the Geology of the South Coast of England, from Bridport Harbour, Dorset, to Babbacombe Bay, Devon.*

By H. T. De la BECHE, Esq. F.R.S. F.L.S. and M.G.S.

[Read March 5, 1819.]

THE portion of the shore of Dorset and Devonshire, which the following pages are intended to describe, and part of which is represented in the annexed section, extends from about three miles west of Bridport Harbour, in the county of Dorset, to Babbacombe Bay on the south-west of Teignmouth. The elevation of the shore within these limits is various. On the west of Bridport the height of the cliffs is not very considerable; but they rise at Golden Cap, a remarkable cliff five miles east of Lyme, to about six hundred feet above the level of the sea; and from that point to Axmouth there is a succession of hills of nearly uniform elevation, and about five hundred feet in height. The cliffs near Beer are much lower than at Axmouth, but they rise westward towards Peak Hill and High Peak, near Sidmouth. At the mouth of the Otter the coast is much lower; but it rises again between that river and the Exe. The cliffs at Dawlish are comparatively low; but they become higher towards Teignmouth, and continue high from the river Teign to Babbacombe Bay.

Plate 8 is a section of the cliffs from near Bridport Harbour to Sidmouth, exhibiting the order of the strata, except between Lyme and Axmouth, where subsided masses of chalk and green sand entirely conceal the rocks below. I have in consequence given a representation of these cliffs as they actually appear; and in the following remarks I shall begin with the superior, and proceed in succession to the inferior beds, advancing in each case from the east towards the west.

Chalk.

The chalk, which is the uppermost of the beds observable on this part of the coast, contains many fossils, and an abundance of flints (occasionally in small seams): its first appearance, in the east, is at Ware Cliffs, near Lyme

Regis, resting upon green sand; and proceeding westward from thence, it forms the caps of the hills of Pinhay, Whitelands, Charlton, Rusedon, and Dowlands near Axmouth. At White Cliff and Beer Head, near Beer, it is in greater strength, resting upon green sand, which, together with the chalk, fills up a large hollow or basin in the red marl of the new red sandstone formation: and from this circumstance the chalk has, in the section, at this place, the appearance of two dips, the one west, the other east. From Beer Head, proceeding westward, the chalk continues to cap the hills, but gradually diminishes in thickness, until it disappears at Dunscombe Hill, a short distance to the east of Sidmouth.

It is worthy of remark that, beneath the sea, seven miles south of the Cobbe Head at Lyme, at the depth of about fifteen fathoms, there are chalk rocks, well known to the fishermen who troll for fish.

Above the chalk of this coast there is almost always gravel composed of unrolled chalk flints. This deposit varies much in thickness: it is in great abundance at Dunscombe Hill, and the tops of several hills capped with green sand are also covered by angular chalk-flint gravel, the debris most probably of former superincumbent chalk.

Green Sand.

The most eastern appearance of green sand on this part of the coast is at Down Cliff*, a short distance to the west of Bridport Harbour, where it forms the top of the hill, resting upon beds of the oolite formation: proceeding westward, it forms the caps of Golden Cap, Shorne Cliff, Black Ven, &c. resting there upon blue lias. At Black Ven, between Charmouth and Lyme, there occur in the green sand regular compact and unbroken beds of chert; but on Shorne Cliff and Golden Cap Hill the same chert occurs, in the form of loose angular shattered fragments, occupying the same position in the green sand formation; and a similar disintegration of the chert is observable upon other hills between Lyme and Sidmouth, which are capped with green sand.

To the west of Lyme, among the cliffs of Ware, Pinhay, Whitelands, &c. the solid and unbroken beds of chert are numerous, and contain many fine specimens of chalcedony.

At Axmouth Point the green sand rests upon red marl. At White Cliff, near Beer, it dips below the level of the sea, still resting immediately upon

* Traces of it only are observable at this cliff, but there is an abundance of green sand about a furlong inland, upon the same hill.

red marl; but it rises again at Beer Head, and from thence towards Sidmouth occupies an intermediate position between the chalk and the red marl, until the former disappears at the summit of Dunscombe Hill, on the west of which the green sand caps the hills as far as Peak Hill and High Peak, west of Sidmouth, where it finally leaves the coast, but reappears in the interior, at fifteen miles distance, in a western direction, on Little Haldon Hill, near Teignmouth, resting upon new red conglomerate.

The green sand in the vicinity of Lyme contains numerous and various fossils; and in compact nodules of it, called Cow-stones by the masons of the country, there are found occasional remains of the crustacea. Plate III. fig. 1. represents a species, the shell of which is so thin that the claws are seldom obtained perfect. The back of a singular fossil crab, from the same kind of stone, which is represented in fig. 2, is the only one of the kind that I have seen.

Among the echinites of the green sand near Lyme, I lately obtained one which belongs to the genus named Echinonaus by Mr. König, in his arrangement at the British Museum; and as it is quite new, I have given it the name of Echinonaus lampas, from its great resemblance to an antique lamp*. See Plate III. figs. 3, 4, and 5.

Lias.

The blue lias makes its first appearance at the base of Down Cliff, rising from under beds of the oolite formation: proceeding westward from thence, it forms the lower and greater part of Golden Cap, Shorne Cliff, and Black Ven: to the westward also of Lyme it forms considerable cliffs; but the line that separates the green sand from the lias, on that part of the coast, is concealed by a beautiful undercliff, composed of fallen masses of chalk and green sand. The last observable portion of blue lias is at a short distance to the west of Culverhole Point, forming some very low cliffs on the shore. The line of separation between the red marl and lias is likewise masked by the undercliff. At the eastern base of Pinhay Cliffs a small portion of white lias rises from beneath the blue, but is soon thrown down by a fault: it reappears at a short distance west of Culverhole Point, and not far from the commencement of the red marl, from which it is separated by a few strata of blue lias.

A few small faults occur in the blue lias under the church cliffs at Lyme; the general dip of the lias in that vicinity is gently towards the south-east.

From the state and elevation of the lias cliffs near Lyme, an excellent op-

* The specimen is at present in the British Museum.

portunity is afforded for the examination of its fossils, and many have recently been brought to light which were before unknown: the most remarkable of these are the remains of a singular animal, which has been named Ichthyosaurus by Mr. König, from its being supposed to form a link between the Saurians and Fish. Sir Everard Home gives it the name of Proteosaurus, and has described several parts of its osteology in the Philosophical Transactions*; and the Rev. W. D. Conybeare and myself have published some further account of it in the fifth volume of the Transactions of this Society.

The remains of this animal are by no means rare; they are principally discovered at Black Ven, and most commonly in the slaty or marly part of the lias. Three species of this fossil genus appear to me very distinguishable; the principal differences consisting in the form of the skull and teeth. I shall content myself at present by giving the names, communis, platyodon, and tenuirostris, to three species hitherto discovered; reserving for a future communication by the Rev. W. D. Conybeare and myself the reasons for so naming them, as well as a detailed account of the differences in their teeth.

Some of the animals of the genus Ichthyosaurus must have been of an enormous size. I have in my possession a vertebra of one of them, which measures seven inches and three quarters in diameter, with various portions of the paddle, which, when entire, must have measured (including the humerus) at least two feet and a half in length†.

Besides the remains of the Ichthyosaurus, there are found in the lias of Lyme the bones of another animal, the Plesiosaurus, described by the Rev. W. D. Conybeare and myself in the fifth volume of the Geological Transactions.

There occur also in the lias at this place singular bodies, which appear to have been the external defensive radii of some fish, and to have been used in the same manner with similar bones of the Balistes tribe. Their shape will be seen by a reference to Plate IV. figs. 1 and 2. They are longitudinally grooved from the apex P to C, which appears to have been the part that protruded out of the body of the fish; and from C to D, the part imbedded in the body, the bone is hollow, as will be seen by the section of fig. 1 at *b*, represented fig. 3. This bone is armed from the apex P to *a*, figs. 1 and 2, with teeth-like bony processes in two rows, placed so as to give a zigzag appearance. I possess specimens in which several of these bones are placed side by side; and it

* See several papers in the Philosophical Transactions, by Sir E. Home, with the reasons for naming it Proteosaurus.—Vols. civ. p. 571; cvi. p. 318; cviii. p. 24; cix. pp. 209—212; cx. p. 159.

† Remains of the Ichthyosaurus are found in the lias, at Watchet, Somerset; at Bath; at the Old Passage, Gloucestershire; and at Whitby in Yorkshire.

might be inferred from this circumstance, that the fish had many of them. The only bones occurring in contact with this fossil, are some which resemble palates or teeth (see Plate IV. figs. 4, 5, 6, 7, 8, 9 and 10). Figs. 4 and 5 are two varieties which are rare; fig. 6 is the most common: all these are mixed with the above-described fin-bones, in a mass of lias which I have in my possession*.

There is a variety of this bone which differs from figures 1 and 2, only in being much narrower, and covered with tubercles instead of longitudinal grooves.

Figs. 1 and 2, Plate V. represent the side and front views of a very rare fossil, which appears to belong to the class of the above-mentioned bones. The curved teeth-like processes are placed in the same zigzag manner, but they are larger in proportion, and separated from each other; there is a single row at the bottom, of the same size as those at top. The two sides of this fossil are covered with small tubercles. This bone is not at all curved.

These fin-bones,—with palates, and a rough thin and bony substance, studded with minute tubercles,—are the only remains of the animal that have till lately been noticed. But an upper and lower jaw, probably belonging to the same animal, have recently been found containing triple rows of teeth. There are in the collection of Colonel Birch two specimens, which show the position of these teeth and the shape of the mouth. Fig. 3. Plate V. exhibits one of the jaws, armed with a triple row of teeth, placed in a manner similar to those of sharks; both jaws being equally armed. In one of the specimens there are four rows of teeth, placed with regard to each other as represented in fig. 4. To the localities of the fossil radii I have to add the Oxford clay, in the vicinity of Oxford and Weymouth, and the same clay at the Vaches Noires Cliffs, between Dives and Villers sur Mer, in the department of Calvados, on the opposite coast of France. Professor Buckland has found them also in coral rag and Kimmeridge clay, at Heddington near Oxford.

The fin-bones vary in length from six to twenty inches: one in my collection measures eighteen inches and a half.

The lias of Lyme contains also various other fossils, among which may be enumerated the following:

A fish remarkable for having rectangular scales, which is much compressed, seldom more than a quarter of an inch thick, most commonly not exceeding one-eighth. It is a very beautiful fossil, from the jet-black lustre of the

* The same kind of bone, but of a different species, is found in the mountain limestone of Clifton near Bristol.

scales: when the fish is fractured, the vertebræ and ribs may be discovered on the inside; the pectoral fins are in general finely preserved. Plate VI. fig. 1, represents one of these fish tolerably perfect; the bones of the skull, however, are not well preserved. I am indebted to my friend Dr. Leach for the following name and description.

DAPEDIUM.

[à δαπεδον, pavimentum.]

Char. Gener.—*Mandibulæ*; dentibus simplici serie: *dentes* lineares, apice emarginati, hinc bifidi. *Palatum*, antice dentibus irregularibus, postice subrotundatis instructum. *Pinnæ*; *dorsalis* unica; *pectorales* acutæ; *caudalis* æqualiter furcata; *analis*, radiis brevibus; *ventrales* breves. *Pellis*, squamis parallelopipedis armata.

Dapedium politum.

The interior of the mouth of one of these fish is represented Pl. VI. fig. 2, and two teeth fig. 3. From one of the short sides of the rectangular scales there is a triangular projection, which fits into a corresponding depression in the scale adjoining it (fig. 4); on the outside of the fish this projection is not visible, the interior part only of the scales being thus provided. These fossils are by no means common: they vary from seven to eighteen or twenty inches in length.

There is another fossil fish, longer considerably in comparison with its breadth than the preceding: the scales are not rectangular except towards the head. These fish are found much compressed, seldom exceeding the thickness of drawing-paper. A specimen of this kind represented Plate VII. fig. 1, is much broader in proportion to its length than those usually found; they are generally of uniform size, seldom exceeding six or seven inches in length.

Fine specimens of pentacrinite occur in seams parallel to the strata of the lias, at Golden Cap Hill.

Fossil wood also is obtained in great variety: there is one kind with a long trunk and branches much compressed, in the marly strata, which is black, splits into small parallelopipeds, is light, and burns with a bright flame and unpleasant smell; the other kinds are generally found in the hard lias limestone, are not compressed, are much knotted, and very compact.

Fossil ferns are but of rare occurrence in the lias near Lyme. The two specimens represented Plate VII. figs. 2. and 3, are from the collection of Professor Buckland, and were obtained from the lias of Axminster: fig. 2 being from the white, and fig. 3 from blue lias.

Many varieties of Ammonites are found also at Lyme, the most perfect occurring in the hard lias limestone or in nodules in the marly strata: these nodules are frequently spherical, and of large size. Among the Ammonites are the following:

Ammonites stellaris *.	Ammonites Brookii.
——— ellipticus.	——— Greenovii.
——— obtusus.	——— Henleii.
——— communis.	——— Loscombii.
——— discus.	——— Birchii.
——— armatus.	——— Königii.

The Nautilus striatus is the only species of that genus that I have yet observed in the lias near Lyme. Among the univalves are also the following:

Trochus anglicus.	Cirrus ———
——— imbricatus.	Melania ———
Helicina expansa.	

The Gryphæa incurva, though generally common in lias †, is not so much so near Lyme.

Terebratulæ occur in abundance, with many other bivalves. Among which are, Avicula inæquivalvis, Modiola Scalprum, Pinna ——, Plagiostoma gigantea.

Small casts of turbines are found composed of iron pyrites, which enters largely into the composition of many fossils of the lias, particularly the Ammonites.

Red Marl, Sandstone, and Conglomerate.

This formation occupies a large portion of the coast of Devonshire; it first appears, on the part of the coast now under consideration, beneath Dowlands near Axmouth, rising from below lias; it forms some low cliffs near Seaton, and from thence, with the exception of White Cliff and Beer Head, it constitutes the lower part of all the cliffs to High Peak, on the west of Sidmouth: proceeding westward, it forms the entire cliffs as far as Babbacombe Bay, where it rests upon limestone. The conglomerate at Teignmouth includes large

* The names here given are those of Sowerby's Mineral Conchology.

† The lias is generally known in France by the name of *Pierre à Gryphite*.

rounded masses of porphyry, from a few inches to two or three feet in diameter: and between Teignmouth and Babbacombe Bay it contains small pebbles, of the same limestone which it rests upon at the latter place.

It will be seen, by reference to the section, that this coast presents two striking examples of the almost sudden termination of strata, close to points where they attain a thickness which is very considerable. At its eastern extremity, the beds of the oolite formation, the thickness of which exceeds three hundred feet, and which at Down Cliff are interposed between the lias and green sand, entirely vanish before they reach the cliff of Golden Cap; and the lias itself, which is from three to four hundred feet thick between Charmouth and Lyme, is, together with the oolite, totally wanting between the green sand and red marl at Axmouth Point. It unfortunately happens, from the covered state of the cliff to the east of this point, and the occurrence of the valley of Seaton between Down Cliff and Golden Cap, that it is not possible to discover the exact place and manner in which these formations originally terminated,—whether suddenly by an abrupt escarpment in the midst of their full thickness, or gradually by thinning off to the point at which they totally cease.

The fault on the sea-shore between Ware Cliffs and Pinhay, is a case of dislocation affecting the lias, similar to those which are seen to advantage at the Old Passage near Bristol.

III.—*On the Bagshot Sand.*

By HENRY WARBURTON, Esq. V.P.G.S.

[Read June 15, 1821.]

I AM not aware that the sand of Bagshot Heath has yet been described with such attention to detail, and reference to localities, as will enable an inquirer to form a correct opinion concerning its geological character. Mr. Smith indeed is stated, in Mr. Farey's Survey of Derbyshire, to have ascertained that it is the highest known stratum in England, and that it rests upon the clay of London; but no proofs of this statement are there given, and I do not find a repetition of it in the memoir that accompanies Mr. Smith's geological map; nor is the map coloured in conformity with this opinion.

Concerning the Bagshot sand it may be asked, whether, like the gravel about London, it consists of diluvian debris, or whether it belongs to a regular stratum, like the sands of the plastic clay? and admitting it to belong to a regular stratum, it will be a question to what position we shall refer it among the beds superior to the chalk.

The sand of Bagshot Heath occupies a district extending from east to west, along the axis of that great depression in the chalk which has been called the London Basin. The length of this district, from its eastern extremity at Esher in the county of Surry to its western extremity at Bromshill Common on the confines of Berkshire and Hampshire, is about twenty-five miles. From Hungry Hill near Farnham to Oakingham, where its breadth from south to north is the greatest, the distance is about twelve miles; but its average breadth is considerably less. The course of its southern boundary is marked by those sandy elevations, which beginning at Esher extend to Claremont, Painshill, Breach Hill, and Ockham Hill near Ripley. After crossing the river Wey, the sand (thinly spread over the stratum which it covers) may be traced across the plain through which the Basingstoke canal passes. Purford Heath and a series of low commons mark its course to Romping Downs and Gravelpit Hill, about seven miles north-east of Farnham, where it again rises into considerable acclivities. At Tuksbury Hill and Beacon Hill Camp, immediately north of Farnham, it attains its greatest elevation; there approaching within less than a mile of the ridge of chalk that forms the southern limit of the London Basin. The western boundary of the sand may be traced from Beacon Hill Camp in a northerly direction, rapidly declining in height, and extending over a low moorish country to Hartford Bridge: it then again acquires considerable thickness, and forms a regular escarpment extending to Broms Hill Common. There its northern boundary commences, passing thence to the south of Oakingham, at no great distance from the forest road to Reading, until it reaches the hill above Egham. A line of sandy hillocks parallel to the valley of the Thames marks the further progress of its northern and north-eastern boundary at some little distance from the river by St. Anne's Hill and Oatlands to the eastern extremity of the sand at Esher.

In tracing this outline I have not entered into any very minute topographical details, because the surface over which the sand extends has been laid down from the observations which I made upon it, in company with Mr. Buckland and Mr. Greenough, in Mr. G.'s Geological Map of England.

The general character of the district, in which the sand prevails, is so well known as scarcely to require description. At its eastern extremity it forms a chain of detached hillocks, and in its central part a high continuous plain, which are strongly contrasted by their barrenness with the fertile country that surrounds them. Such indeed is the character of the vegetation and the general appearance of sterility in the worst parts of this district, that, when the neighbouring fertile country is hidden from the view, one may suppose one's self upon a desolate mountain moor in the border country. Common ling is the natural growth of the meagre sand that forms the higher parts of this district. In the lower parts however, in which some argillaceous beds intervene between those of sand, the vegetation is of better quality; and the lowest parts of all, which consist of a sandy loam resting upon clay, are often (as upon the skirts of Windsor Forest) highly favourable to the growth of large timber.

With regard to the position of the sand, the hill above Egham affords unequivocal proof that there at least it lies immediately upon the surface of the London clay. In the clay-pits to the south of the great western road, near the foot of the hill, the clay is seen characterized by its blue colour, by many of the most common of its fossil shells, and by its septaria. The sand rests immediately upon the clay, increases in thickness as the hill rises in height, and is continuous with the great body of the sand that extends from Egham Hill to the westward.

That the position of the sand observed at Egham Hill agrees with its position generally throughout the district which it occupies, cannot be doubted.

For the boundary-line which we have traced round the sand, from its eastern extremity at Esher, is also the boundary line which marks the appearance of the London clay, a zone of which completely encircles the sand, exhibiting itself at a lower level than the sand, and emerging from beneath it.

The London clay may be traced round the sand from Kingston Common at the foot of Esher Hill to Claygate Common and Jessop's Well; thence to Leatherhead Common, Bookham Common, and Ripley, where septaria are found in making ditches. A well 180 feet deep was dug in clay at Horsley, in the refuse of which I observed septaria and some of the commoner shells of the London clay. From Ripley the clay may be traced to Worplesdon. The next place along the boundary-line where I have observed the clay is in some pits in Crondall parish, north-west of Farnham; the stiff land at Hartley Row is probably occasioned by its presence.

Clay with septaria and pyrites is found in pits below the level of the sand in the parish of Finchhampstead near to Broms Hill. At Sheep Bridge, between Stratfield-le-saye and Reading, the clay appears with its septaria in the brook which crosses the road at that bridge; and the clay and septaria are well known to the well-diggers in that neighbourhood. Still further to the west, at Mortimer near to Silchester, I found septaria in a bank of blue clay; and it is highly probable that the clay extends still further to the west at the foot of the high ground which lies to the south of the vale of the river Kennet.

From Binfield a bed of clay may be traced without interruption along the northern acclivity of Windsor Forest to St. Leonard's Hill, Cooper's Hill, and thence to Egham, where (as we have already seen) the nature of the clay is fully exhibited.

It appears then that the sand uniformly rests upon the London clay: it remains to be ascertained whether it is to be considered as diluvian debris, or as belonging to a regular stratum. Since the sand has not hitherto been found extending beyond the limits of the London clay, or immediately incumbent on the chalk or any other bed beneath the London clay, it would seem probable, for this reason alone, that it belongs to a regular stratum; and this opinion has been confirmed by an attentive examination of the beds of the sand itself.

Those parts of the sand which are nearest the surface are generally more or less mixed with angular chalk flints and other diluvian debris, such as is found upon the surface in almost every part of the London Basin. But below this diluvian matter I have not observed any angular flints, nor any beds but such as in the aggregate materially differ from those which are of diluvian origin. The highest of the undisturbed beds consist of a meagre sand, somewhat ochreous, and not distinguishable from the diluvian sand by any circumstance excepting the absence of angular masses of flint. At a lower level are found beds of foliated green clay, alternating with beds of green sand: extensive beds of this clay are found to the north of Chobham Park, on the road from Chertsey to Bagshot, where they are worked for the making of bricks and coarse pottery. It is in the beds below this green clay that we find the most unequivocal proof of the sand of Bagshot Heath belonging to a regular stratum. These lowest beds are found on descending the acclivity to the south of Chobham Park. They consist of alternations of white, sulphur-yellow, and pinkish foliated marls, containing abundant grains of green sand, regularly stratified, and inclosing fossil shells, such as have not hitherto been found in England in any other bed above the chalk with which I am acquainted. The entire thickness of these lower beds may be about forty feet. The white foliated marl bears a strong resemblance to that of Menil Montant, in which the Menilite is found, near to Paris.

The shelly matter of the fossil shells which these beds contain has altogether perished, so that it is impossible to identify the species, though the genera may be determined. The most abundant of the shells is the cast of a crassatella, agreeing I believe with a crassatella found in the Paris Basin at Meudon in the *calcaire grossier à matière verte,* and deposited in the Society's collection. The only other shells which I have found are a pecten, and what appears to have been a trochus.

At the base of the hill in which these beds are found, a blue clay, which I suppose to be that of London, makes its appearance.

Similar beds of foliated marl are found on the continuation of the Bagshot sand at Addlestone near to Chertsey, but no shells have been there observed. The foliated marl is there covered by a clay which strongly resembles in texture, though not in position, some of the varieties of plastic clay.

At the foot of St. Anne's Hill the beds which lie nearest to the London clay are different from the preceding. They consist of masses of rolled chalk-flints, closely resembling those of the pebble-bed in the plastic clay, intermixed with green sand, green foliated marl, and stony concretions of that sandstone which is so generally dispersed in masses over the surface of Bagshot Heath.

I do not believe that the Hertfordshire puddingstone has been derived from the stony concretions of this bed, but rather from those of the plastic clay; the cement of the puddingstone being composed of much purer siliceous matter, and not being so ochreous as that of the grit of Bagshot Heath. The Hertfordshire puddingstone and the greyweathers of Marlborough downs and Abbotsbury contain angular chalk-flints; and I have observed only *rounded* pebbles in the grit in question.

Among the diluvian debris dispersed over the surface of the heath, quartz crystals are not uncommon. Near Farnborough are found upon the surface fragments of an arenaceous limestone, containing many fossil shells, and among the rest, dentalia. It is to Mr. Stokes that I was first indebted for the information respecting these fragments.

I have lately succeeded in ascertaining the bed from which these fragments are derived. They come from the stony concretions which are found in the beds of sand belonging to the plastic clay, that extend through the low country between Windsor and Reading at the foot of Windsor Forest. They resemble the stony concretions that are found in the same bed at Sundridge Park near Bromley, and agree, perhaps, with those of Bognor rocks.

The existence of these specimens was first announced by Lord Grenville to my friend Mr. Buckland, in company with whom I examined them *in situ*.

The place from which the specimens of these stony concretions in the plastic clay which I now send were taken*, is the water-course lately made for the purpose of draining the newly-inclosed lands of Windsor Forest, on the road that leads from Hollyport to Binfield. The sand with its concretions there rests upon variegated plastic clay. The shells are the Reading oyster, a Pecten, a large and small Cardium, a Pectunculus, Nucula margaritacea, two species of Citheræa, a shell resembling Solen radiatus, a Tellina, a Dentale, Strombus pes-pelicani, Calyptræa trochiformis in great perfection, and several imperfect turbinated shells. There is also a shark's tooth, pyritous wood, and what appears to be the seed-vessel of a marine plant. It is remarkable that the Cerithia, which are found in the same beds in Sussex and near to London, are wholly wanting in the beds at Reading and at the spot in question.

I propose at some future period to examine the sands of Dorsetshire and Hampshire, which, I have very little doubt, will be found to belong to the same formation as the sand of Bagshot Heath.

* The specimens here referred to are in the Museum of the Geological Society.

IV.—*Supplementary Remarks on Quartz Rock.*

By JOHN M^cCULLOCH, M.D. F.L.S.

CHEMIST TO THE ORDNANCE; LECTURER ON CHEMISTRY AT THE ROYAL MILITARY ACADEMY; AND GEOLOGIST TO THE TRIGONOMETRICAL SURVEY.

[Read November 3, 1819.]

HAVING on two former occasions continued the imperfect history of Quartz Rock, originally given in the second volume of the Society's Transactions, as fresh materials occurred, no apology is required for this additional notice, the result of some investigations made during the present summer (1817). It is not necessary to enter into further details respecting its geographical extent in Scotland, although large additions might be made to the tracts which were described as composed of it; the principal objects of the former communications having been already attained in the proofs adduced of its importance as a member of the primary stratified rocks. The present remarks relate solely to the geological relations of quartz rock; and their object is to confirm and extend some circumstances respecting those which, although formerly mentioned, were either too limited to be quite satisfactory, or were attended with some degree of obscurity.

The relations of quartz rock to micaceous schist, to argillaceous schist, and to graywackè, have been fully described in the former papers. At the same time it has been observed, that it graduated on some occasions into gneiss, and also alternated with certain varieties of that rock, as well as with the micaceous schist which accompanied it. But as the gneiss in these cases was of an indeterminate, and, perhaps, of a disputable character, while it seemed rather a modification or a *subordinate* member of the micaceous schist, than an extensive and independent mass, it still remained a doubt whether quartz rock did actually alternate with gneiss in an unquestionable manner, and on a scale corresponding to its alternation with micaceous schist. That doubt has now been removed by a further examination of the west coast of Sutherland, where it abounds; as I formerly mentioned in the original communication on this subject.

The character of the gneiss is here as decided as its extent is unquestionable; since it forms a very large portion of the country, and presents all its varieties from the granitic to the schistose. And although its structure is such that it cannot always be satisfactorily distinguished from micaceous schist, yet these cases bear no proportion to those in which its character is strongly marked; while, over a large space, it presents that approximation to the granitic disposition which characterizes the gneiss of the Western Isles. It is also distinguished by the presence of granite veins, and by the occasional occurrence of very extensive masses of granite.

This great mass of gneiss is succeeded in some places by the tract of quartz rock formerly mentioned, and alternates with it in others. Thus the latter rock is found under a great variety of position; sometimes in a detached state, occupying the summits of those mountains of which the chief mass consists of gneiss; at others, covering considerable tracts of country, and forming the lowest as well as the highest land. Examples of the former will be found in Ben Stack and in the northernmost Ben More; while the great tract from Ben More Assynt to Canasp and Cuniach, presents an instance of the latter disposition. But this change is not always effected without an alternation of the two; not merely that slight alternation of a few beds which so often occurs at the point of contact between approximate rocks, but one that involves masses of almost mountainous bulk.

It is necessary to remark, that the leading direction of the beds of gneiss, as well as of the rocks which accompany it in this tract, is north-easterly; that direction, however, from the usual inconstancy and undulation of the beds, being seldom determinable within four or five points of the compass; since it is subject to vary twenty degrees or more from this average bearing. The dip is still more various, but may be generally comprised between the angles of ten and thirty degrees. In both the places which I shall point out as presenting the alternation in question, the direction appears to be E.N.E. and the dip about fifteen degrees.

One instance of alternation is seen at the north side of Glen Dhu, and near its upper extremity. The bed of quartz rock appears to be about one hundred feet thick, and reposes on that gneiss which extends to the western sea. It presents its broken face to the southward, and is easily examined. It consists of very even and parallel strata, of an extremely compact variety, subject to crack in numerous directions from the injuries of the weather, and then crumbling so as to form a slope extending from the foot of the precipitous face to the shore of the Loch. Its predominant colours are white, yellowish, and gray; but many of the beds are of a pink, others of a brown purple hue;

while some present the colour and, except in their superior compactness, the aspect of red sandstone. A few are mottled with red and white, in spots, stripes, or irregular stains, such as are well known to occur in many varieties of the lowest red sandstone. This is in fact an instance of the association of quartz with the primary sandstone described as occurring in Sky.

This mass is followed by a similar gneiss to that which lies below it, and which not only forms the principal part of Ben More, but extends in succession to the head of Loch Shin, and so on, to a distance which I need not here specify. This is the most conspicuous and satisfactory alternation found in these hills, but not the only one; since, in crossing the ridge to Loch More, the quartz rock is again found on one of the inferior summits. There are no obvious means, however, of determining whether this mass also alternates with the gneiss; nor did it appear of such moment as to call for a laborious search, as the fact is sufficiently proved by the appearance of the beds on the shores of Loch Dhu.

Similar arrangements are seen on the south side of that inlet of the sea which flows through the Cylescuagh, into Glendhu and Glencoul, and which is without a name.

It is unnecessary to dwell more particularly on these; since the alternation of the gneiss is established in a similar manner, by the positions of both rocks, and by the conformity of their dips; while the mineral characters of the quartz rock are the same as those of the beds already described. The object of this paper not being of a geographical nature, I shall not at present trace the quartz rock further; since better opportunities of entering fully into this branch of the subject will hereafter occur.

It would have been desirable, in the particular instance first described in this paper, to have traced the actual contact of the gneiss and quartz rock where the alternation is most demonstrable: but, unfortunately, as is too often the case, the nature of the ground does not admit of it. Those parts of the hills where the rocks are bare, and where these contacts should be seen, are precipitous and inaccessible; while the flatter, are, from their more gentle declivity, covered with an impenetrable mass of rubbish. In every respect indeed the country is of the most difficult access. But the contact in question and the nature of the transition, though they cannot be seen here, are to be found in many other situations where the two rocks exist together. They can thus be traced in Ben Ay, in Ben Klibrigg, and in other parts of Sutherland. In these cases there appears a gradual transition for some space between the two; the gneiss first putting on the aspect of micaceous schist, which then passes into a micaceous and highly schistose quartz rock, and ultimately into pure quartz rock, of various degrees of compactness and induration*.

On a former occasion† I pointed out an alternation which quartz rock forms in the Isle of Sky with the red sandstone. That observation is no longer solitary; since the west coast of Sutherland also produces many instances of the same nature, besides that at Glendhu just mentioned. As the description of the conglomerate and sandstone of that district is not my object in the present communication, it is sufficient to say that they resemble the corresponding rocks of Sky, above referred to, in every respect; presenting the same varieties in colour, composition, and induration. The alternation of this sandstone, under its several modifications, with the quartz rock, is visible in many places; and when the large-grained conglomerates form the alternating bed, the appearance is not a little unexpected.

These alternations occur in two ways, both in single beds and in mountain masses; in the former case differing from the example described in Sky, where no interchange of beds on a small scale was observed. The beds in question, like those above enumerated, have a north-easterly course, with a southern dip, frequently at angles not exceeding 10°. Among the places where these alternations are visible the most accessible are Cuniach and Ben Stack. To examine the former mountain, if the object is to trace the alternations on the great scale, a considerable tract must be compared; but in various parts of the outskirts of the mountain the minor alternations are accessible with little labour. Ben Stack presents these latter only.—It is unnecessary to enter into more details of localities, as many of them cannot be particularly described, for want of marks; and the geologist who is inclined to undergo the toil of traversing this trackless and abandoned region, will not regret the additional labour of investigating more minutely the only objects which it presents to reward him for the sacrifice.

FURTHER REMARKS ON QUARTZ ROCK.

1818—1819.

The object of these concluding remarks is to supply that which was wanting in the former supplements, and to complete, as far as the history of

* These transitions are remarkable for the evenness and the parallelism of their fracture; producing slates very well calculated for roofing in windy climates; but still more applicable to the purposes of paving, since they afford slabs of ten or twelve feet in length, perfectly even, and easily shaped by the hammer.

† Geological Transactions, vol. iv. p. 273.

quartz rock is known to myself, the materials from which a general account of its characters and geological connexions may be deduced.

In a very extensive review of the north-western coast of Scotland, and among the rest of that tract described in the preceding paper, the observations which it contains have been both confirmed and multiplied;—quartz rock having been found to extend over considerable spaces in Ross-shire, in places which I had not visited in the summer of 1817. In these it occurs in alternation with gneiss, as well as with that red sandstone, which, from its situation both in Sky and on the main land, I have thought fit to rank among the primary rocks. In these cases there is sometimes an obvious gradation between the latter and the quartz rock; but in many places the distinction between the two is strongly marked. In the predominant examples, however, it appears to alternate with gneiss, and often in beds, or in a series of repeated beds of equal dimensions; and this distinction between the two rocks is here also marked almost invariably with great precision.

The entrance of the eastern side of Loch Eribol consists entirely of quartz rock; and it is here very remarkable for the magnitude, number, and variety of the caves which it contains, and for the singular and picturesque forms of various kinds into which it is broken.

Here, as at Macarthur's Head, in Isla, the quartz contains pyrites in considerable quantity; and the effect produced by the decomposition of this latter substance, is such as to be very deceptive; the exterior surface of the cliffs of quartz rock being frequently stained of a reddish brown hue, so as no longer to resemble that substance, so generally conspicuous by its whiteness; but very exactly imitating the colour of granite. The deception is often rendered perfect by the forms of the rock, and can only be detected by manual examination: and it will be useful to have pointed out this circumstance; since, either from confidence in the supposed facility of determining the characters of rocks at a distance, or from the impossibility of obtaining a near access, geologists of confined experience may easily be led by it into erroneous conclusions.

In Loch Eribol the quartz rock also presents examples of considerable curvatures, which, in general, is a very rare occurrence; as, in most cases, where sudden flexures or contortions occur in the micaceous and argillaceous schists by which it is accompanied, it is itself fractured and not bent. Near the Whiten head, in this inlet, a remarkable example of this limited curvature may be seen; the exterior parts having fallen away so as to leave a large portion exposed in the form of a semicylindrical body.

In a former paper it was remarked, that a considerable tract in Mar consisted of quartz rock; but I was not then aware of the exact mode in which it occurred with respect to the other rocks with which it is there associated. This whole district presents a perpetual alternation, both in the great and small scale, of gneiss and micaceous schist, but principally of the former substance, with the rock in question. And here, not only the alternation between the gneiss and quartz rock is so frequent, but the apparent transition between the two is so perfect, that it is quite impossible, without minute examination of the fractured rock, to determine which is present; the external aspect and general characters of both being precisely the same. Partly from this frequency of alternation, and partly from the impossibility of determining the nature of the rocks without such minute investigation as is impracticable, it is not possible, in a map, to express the nature of the rocky strata, except in a general manner.

The association of gneiss with quartz rock is less common in the northern parts of Aberdeenshire; but where the latter substance occurs there, in the vicinity of granite, it is attended by appearances of an interesting nature, more particularly as respects the history of that compound. Ben-na-chie, among other places, presents a very remarkable and accessible example of the changes of character which the quartz rock thus exhibits in contact with the granite. The regularity of the stratification is disturbed, and in many places the strata are also fractured and displaced. Where the fractures are considerable, the parts are sometimes reunited by minuter fragments and by crystalline quartz; and in many places these fragments are so numerous, that the whole mass forms a breccia or an angular local conglomerate of a peculiar character. In other cases cavities remain in the intervals; and their surfaces are then generally covered with minute drusy crystallizations of quartz.

Many of these beds, also, lose the character of quartz, and put on the aspect of chert, sometimes gray, and at others of a reddish, or red-brown colour. Others, of a more argillaceous character, resemble jasper, and are indeed in many places not to be distinguished from the most siliceous varieties of that mineral; nor is it uncommon to find an intimate mixture of quartz, chert, and jasper in the same bed, sometimes disposed in an irregularly laminar manner, at others intermixed in great confusion.

If we recollect the variable composition of quartz rock where it occurs at a distance from granite, it is not difficult to account for the peculiarities of character in the instance under review. They are in all respects analogous to those which take place in different rocky strata, not only where they approximate to granite, but where they are in contact with masses or veins of the trap rocks. The production of chert and jasper is easily accounted for, by supposing the original quartz rock to have contained felspar in different proportions; and the peroxidation of the iron, equally accounts for the red colour of the altered rocks. The fracture and displacement are in all respects analogous to those which occur among strata in the vicinity of trap; and the whole presents an additional mass of evidence respecting the analogous powers of trap and granite in altering the characters and conditions of the strata with which they interfere. If the action of heat be admitted in the one case, it is not easy to see how it is to be refused in the other, when the effects in both so exactly correspond.

The last association of quartz rock which has been discovered by the investigations of 1819, is of a more intricate nature; and with a sketch of that I shall finally terminate these supplements. The Transactions of the Geological Society having formed the repository of these progressive remarks on a rock before obscure, it is unnecessary to apologize for the wish to place the whole in the same work; although a full view of this part of the subject is given in the author's account of the Western Islands of Scotland.

The peculiar series here to be described consists of a repeated alternation of this rock with micaceous schist, chlorite schist, and hornblende schist; the two latter presenting many remarkable varieties of composition and texture. This series extends over a considerable tract of country, in very regular stratification.

The beds of these different rocks rarely exceed a very few yards, and are often but a few inches in thickness. In general the quartz rock forms a bed of the largest of these dimensions, and is accompanied by a small one of micaceous schist. The other substances follow in an order more or less regular; and thus the series is repeated, with various inclinations, for a space of not less than twenty miles across the whole. The linear direction is remarkably exact, and the beds exhibit no marks of disturbance.

In these beds few examples occur, as far as I examined it, of that variety of quartz rock which contains felspar; and those which are found differ much in aspect from what occurs in association with gneiss, in which that mineral forms so conspicuous an ingredient. The predominant beds are simple, compact, granular or splintery, but occasionally also micaceous.

In concluding this final supplement it will be useful to enumerate the leading varieties of quartz rock, as far as respects its mineral characters; but the fuller details of these must unavoidably be reserved for a more appropriate place.

Quartz Rock is

Simple, or formed of quartz alone.

a. Compact, and resembling that which occurs in veins.
b. Compact, and, at the same time, obscurely granular.
c. Compact, with a small splintery fracture.
d. Granular, with grains of various sizes, and highly compacted.
e. Granular, and more or less loose, so as to resemble the secondary sandstones.
d. Laminar; often slightly schistose.

Compounded—of quartz and felspar.

a. Grains of felspar imbedded in compact quartz.
b. A granular mixture of various proportions of these two minerals. This variety presents some modifications similar to the preceding, on which it is unnecessary to dilate.

Compounded—of quartz and mica.

a. Mica imbedded in quartz.
b. An arenaceous mixture of the two.
c. A laminar mixture; of various aspects, and passing to micaceous schist.

Compounded—of quartz and argillaceous schist.

a. A laminar alternation of the two substances on a more or less distinct scale.
b. Argillaceous schist uniting grains of quartz, and thus passing into graywacke.

Conglomerate quartz rock.

This presents many varieties; the fragments of quartz being either angular or rounded, of various sizes, and intermixed with mica and schistose blue clay, and with fragments of argillaceous and of micaceous schists, and even of jasper. These pass into coarse schists, resembling the graywackes of similar character.

Quartz rock has not hitherto been found to contain any imbedded minerals, except pyrites and garnet.

V.—*Additional Remarks on Glen Tilt.*

By JOHN McCULLOCH, M.D. F.L.S.

CHEMIST TO THE ORDNANCE; LECTURER ON CHEMISTRY AT THE ROYAL MILITARY ACADEMY; AND GEOLOGIST TO THE TRIGONOMETRICAL SURVEY.

[Read June 16, 1820.]

THE observations which were made on the structure of this valley in 1814, appeared in the third volume of the Transactions of the Geological Society. Since that period, I have had (in 1817) an opportunity of traversing the same ground, and in somewhat greater detail. In so doing I have found no occasion to change the opinions then formed respecting its structure. On the contrary, a greater intimacy with its parts and with their disposition, and an increased practice in observation, have tended to confirm the remarks originally made. A slight correction only is required, resulting from a much wider investigation than the former; it respects gneiss, and will be introduced in its proper place.

Several additional circumstances have however occurred, which are not only interesting in themselves, but will probably be acceptable to the Society, as tending to render the account of this spot more complete. I need make no apology for the detached form in which they are recorded, as they do not admit of any useful arrangement.

Granite Veins.—Since these veins have here been traced to the great mass of granite, it would be interesting to know how far they extend from it, as there are so few opportunities of pursuing the courses of granite veins to a central mass. Those formerly described are immediately lost in the hills that form the south-eastern boundary of the valley; although it is not possible to discover whether they actually terminate near the junction, or are prolonged far into the superincumbent strata. About a mile, however, from Blair, on the northern bank of the Tilt, I have since observed one which is about three miles distant from the nearest visible granite: it is but a few feet wide, and presents no peculiarity of structure. It is evident, however, that its apparent distance from the granite is no test of its real one; as the mass of granite may here be subjacent to the schistose rocks at no great distance, although no where coming to the surface. I may add also, that minute ramifications of granite are found traversing the schistose rocks, even in the bed of the Banavie, within the grounds of Athol House.

Trap Veins.—One of these was noticed in the original communication, already referred to, and I have since observed another at Gow's Bridge, during a low state of the waters of the river, which was not visible on former occasions. Its course is nearly conformable to the direction of the strata, which however it also intersects; and it presents no peculiarities either in its structure or its junctions. In many parts of Scotland such veins would be unworthy of notice; but they are deserving of record in a place where they are of very rare occurrence; which is the case wherever we recede far from the great overlying masses which abound in the middle, and on the western shores of this country.

Limestone.—Among the micaceous schist and gneiss which form the northern boundary of the Tilt, and not far from its junction with the Garry, there occurs a remarkable variety of primary limestone. It is of a laminated structure, each lamina of calcareous matter being separated from the next by one of mica. The calcareous laminæ rarely exceed the twentieth of an inch in thickness, and are often much less. The stone is readily fissile in the direction of the micaceous lamina; and as the calcareous one is only visible on the edge of the fractured specimen, on account of the continuity of the micaceous surface, it is easily mistaken for micaceous schist. The calcareous part of the stone is of a pale blueish-gray, the micaceous of a pale brown; and, as the laminæ are perfectly flat and parallel, a section at right angles to them presents an appearance as regular as a succession of ruled lines.

The yellow marble, described at page 295 of the Memoir above mentioned, is of an uniform ochre colour only in one point. A more complete examination of the beds has shown that the predominant mass is of a white colour, intersected by numerous reticulating veins of pale ochry yellow. At the edges of the bed, where it comes into contact with the schistose rock, it assumes a grayish colour and loses its beauty; while it acquires great hardness and an argillaceous aspect. Marbles of this colour are much esteemed by architects on account of the warmth of their tints and the tranquillity of their effect in interior decoration.

The pink marble mentioned at page 306 has since been found in its natural place, between Fealair and the head of Glen Fernat. It is part of a bed which, like many of those before described, alternates both with micaceous schist and quartz rock; the beds every where changing their characters, both in their alternations and in their lateral progress. In some places it is of a continuous and considerable thickness; while in others the laminæ do not exceed an inch or two, and alternate with blueish-gray earthy limestone and with micaceous schist. The texture is large-grained, and the fracture glistening; and its colour is a fine full-toned pink, wherever it does not pass into the gray just described. If a correct taste had not long since condemned the attempt to imitate colour as well as form in statuary, the tint of this marble would have rendered it an admirable substance for the representation of the naked figure. Nor does it appear applicable to mere architectural decoration; being of too insipid a character to stand alone, and ill adapted to harmonize with the colours prevalent in this class of ornament.

As this colour is of rare occurrence in limestones, I may point out another bed of the same nature, which is found in the hills that bound the Tilt to the southward. Like the other limestones already described, it alternates with the quartz rock and other associated substances, reaching from the Fender towards the house of Lude. It is of an extremely fine texture, minutely granular, yet highly crystalline, like the finest arenaceous specimens from Carrava, and is so hard that an ordinary knife scratches it with difficulty. Its colour is neither so strong nor so continuous as that of the preceding, and indeed often vanishes altogether; but, wherever it exists, it borders more on the dilute crimson than the former. It is exceedingly translucent on the edges, and transmits a redder light than it reflects.

Besides the white marble already described as occurring at Gow's Bridge, another large bed exists in the hills that form the south-eastern boundary of the valley. In geological position it lies at a great distance from the former, an immense series of beds of quartz rock being interposed. It is found at the foot of Cairn Lia, not far from the Queen's road, and in the lands of Lude. It is of a large-grained texture, and, where it is purely white, cannot be distinguished from the Parian. As far however as it is hitherto accessible, there is not much to be seen of so pure a quality; the predominant portion being tinged with a slight gray hue, such as would be produced by wetting a white substance capable of absorbing water. Hence also it displays a sort of transparent surface, which destroys its value in an œconomical view. This gray colour seems indeed in a good measure to depend on the presence of water in the stone, as it is removed from many of the specimens by drying, when they assume a tolerably pure white aspect with a considerable lustre. It is not contaminated with mica, like the beds formerly described by the river side, and might probably, if fully opened, prove valuable, as it exists in considerable quantity, and in an apparently undisturbed state, the granite being far distant.

In a former paper, published in the second volume of the Geological Transactions*, I have described a bed of limestone containing hornblende, which occurs at Loch Laggan. As this circumstance is not common, I may point out another example of it, to be observed within the tract at present under consideration: it is in one of the beds which cross from the Tilt through the grounds of Lude. The rock is of a pale dove colour, and of a large grain; and is intermixed throughout with very minute particles of black hornblende, not exceeding in size a pin's point.

Quartz Rock.—I have on different occasions shown that quartz rock often contains associated beds of breccia, in which respect it possesses an analogy to the secondary sandstones. In these cases the breccia consists of fragments of the same original rocks, which, in a more comminuted state, form the finer parts of the deposit, and is evidently of the same period of formation. I had at that time found no breccia connected with quartz rock itself, and composed of fragments of that rock reunited; but such a one occurs near the Fender, in the hilly ground south of the Tilt. Such local breccias are not uncommon among the secondary rocks, and they are particularly well known among the calcareous strata, where they form a considerable class of ornamental mabrles.

In the case of quartz rock, as well as in those now mentioned, the breccias must be supposed to have originated in some violent motion or fracture of the beds, without any material change of place; the parts being subsequently reunited by siliceous infiltrations, in a manner already pointed out in an article on quartz rock published in the fourth volume of the Geological Transactions†.

Gneiss.—In my first communication on Glen Tilt I questioned the occurrence of this rock as an extensive member of the strata which lie on the granite. There appears no reason to change this statement, as far as relates to the hills which bound the southern side of the valley, and which alone were described in the paper. But the case is otherwise with respect to the hills on the northern side, which I had not then examined; since gneiss occurs there in considerable abundance, together with quartz rock, micaceous schist,

* Page 435. † Page 266.

and different varieties of hornblende schist. It is probable therefore that the observations of Professor Playfair and Lord Webb Seymour have differed from mine, solely from the circumstance of our having examined different points on the same ground.

Marl.—I find, on examining the Perthshire agricultural report, that the marl described in my original memoir (page 316 &c.) has been observed in other situations. It has merely however been looked on with the eye of an agriculturist, and apparently confounded with those marl beds found on flat ground under peat, which are the produce of subaquatic shell-fish, and indicate the places where small lakes have formerly existed.

Quartz.—Besides the varieties formerly described, I have found hyaline quartz in veins, in the micaceous schist of Glen Tilt: a circumstance by no means common, as the quartz of veins is almost always opaque. The specimens in question are sometimes colourless, at others of a pale smoky brown, resembling the specimens that accompany the titanite in the chlorite schists of Killin. I may also add, that groups of crystals of opake quartz, of a very large size, occur among the granite of the surrounding mountains; a circumstance deserving of notice, only because of its rarity throughout Scotland; where, unlike to Cornwall, the quartz is rarely found in a crystallized state.

Pinite.—Besides the brown porphyry in which this mineral is found, it occurs in two other varieties, the one of a pale brownish pink colour, the other of a pale gray. In both these rocks it is more abundant than in the one formerly described; while, from the contrast of colour, it is at the same time more conspicuous. I may add that the porphyries of these hills are often of a very compound structure, containing, besides their characteristic ingredient, crystals of quartz, mica, and hornblende.

Pyrites.—Occasionally small irregular nodules of copper pyrites are found in the quartz veins that traverse the schistose rocks. Iron pyrites is also found crystallized in cubes which are sometimes an inch in size. It seems to occur indiscriminately in all the rocks; in the granite, the schists, and the limestone; but it is most frequent in the micaceous and hornblende schists.

Sphene.—Although this mineral is of most frequent occurrence among the granites that contain hornblende, it is not limited to those varieties. I may also remark that the magnitude of its crystals, in the specimens in which it occurs, bears a proportion to the magnitude of the particles of the rock; being minute in those of a small grain, and large in those of a coarser texture.

Titanite.—I have mentioned this substance as occurring in Scarsough and in Ben Gloe*. In both instances it is but in small quantity; but I have since found it in considerably greater abundance in the hills that bound the southern side of Glen Tilt. It is there crystallized in prismatic forms, and imbedded in nodules of chlorite, which are associated with quartz veins, traversing micaceous schist; a situation exactly resembling that in which it is found at Killin. In many cases the crystals are fractured, or else geniculated; for it is often by no means clear to which of the two causes the deviation in their rectilinear directions is to be attributed. In one instance a specimen occurred in which a crowd of capillary crystals, as fine as the finest hair, traversed a vacant cavity in the quartz; and it is not unusual for the larger prisms to shoot through vacant spaces in the vein. I may add here, that I procured at Killin one specimen of a hollow crystal of this substance, the prism of more than an inch in length, having a perforation in the direction of its axis. This is a circumstance of no very common occurrence in crystallization; and I may, for that reason, remark that I have also met with it in the tourmalin: the specimen in question being a mere tube, very thin, and with a large vacancy.

Tremolite.—Besides the varieties formerly enumerated, I have since observed the following; which it will not be useless to mention, on account of the diversity of aspect presented by this mineral, and the obscurity which attends some of the more uncommon modifications.

1. Compact and granular; or at least so little marked by prismatic forms that they cannot be distinguished except in certain favourable fractures. It differs from the granular variety formerly described, in being of a much coarser texture, and of an obscure purplish gray colour.

2. White and granular, with a schistose fracture. I formerly described this variety, as far as its texture is concerned; but the stratum I had then observed was of a massive structure: in the present instance the mineral occurs in the same situation, but is readily divisible into thin laminæ.

3. The third variety worthy of notice is a compact aggregate of minute spherules, not exceeding the tenth of an inch in diameter. It is of a watery gray colour, and each spherule is found, on fracture, to consist of capillary

* Geological Transactions, vol. iii. p. 53.

crystals radiating from a centre: it presents a singular as well as beautiful specimen for collectors.

4. Transparency, at least to a certain degree, has I believe been considered a characteristic of tremolite. A variety is however found in this place of a whitish green colour, and perfectly opaque. As is usual among the more common kinds, it is radiated; the radii being about an inch in length. The form of the crystals is however imperfect; and their disposition more confused than in the ordinary kinds.

5. Tremolite is found also among the limestone of this district, in other situations besides Gow's bridge, where I originally discovered it. The most remarkable variety which occurred consists of broad laminæ, radiating from a common centre, and of course presenting greater dimensions at the circumference than the centre. The length of the radii extends to four or five inches, and their breadth from an eighth to a sixth, or even to a quarter of an inch.

6. The next variety which appears to merit notice consists of spheres, from half an inch to an inch in diameter, imbedded in the limestone. They are generally placed at a small distance from each other, and, as they are much harder than the including rock, are readily discovered in water-worn fragments; often projecting a semidiameter beyond the worn surface. Occasionally they present a fibrous and radiated structure; but they are often extremely compact, and the structure consequently very obscure. They are of a sea-green or pale beryl colour.

7. The very fine fibrous variety occurs also here of a pale green colour, and in considerable quantity. The fibres are fasciculated and parallel, often exceeding six inches in length, and either straight or curved; and the lustre resembles that of silk.

8. Lastly, this mineral is found of a similar green colour, but in the form of crystals, from an eighth to the fifth of an inch in diameter, entangled together so as to constitute a solid mass of considerable hardness when dry; but, like all these substances, extremely tender when first taken from the quarry.

I formerly mentioned that tremolite and sahlite were found in the same place, and in contact; but was not then quite aware of the intimacy of their connexion. They are occasionally so intermixed together, that it is not easy to be certain that the one mineral does not graduate into the other: and it is not impossible that such a transition does actually take place. It is also a remarkable fact, that wherever I have observed sahlite in Scotland, there tremolite is likewise found, and always in the same intimate union.

Felspar.—Crystallized felspar is sufficiently rare in Scotland to render any notice of its localities desirable. It occurs in veins in micaceous schist on the hills that form the southern boundary of Glen Tilt. The substances associated with it in the same vein, are quartz and crystallized mica; the whole forming a sort of granite vein, all the ingredients of which are independently crystallized. It is commonly white, occasionally with a very pale tint of flesh-colour. Although the specimens are of considerable size and the crystals numerous, they are not so well defined as to permit their forms to be easily described. Among them I observed flat rhombs and prisms of various complicated figures, rendered more so by numerous irregular truncations of their summits, but very obscure, either from the manner of their adhesion, or from their coalescence with others. Whatever interest the almost endless modifications of crystals may possess, I know not that there is any thing in this case, more than in many others, deserving of minute details; the more so that, without figures, the descriptions of complicated geometric forms are scarcely to be rendered intelligible. One of the specimens which I procured in this place, exhibited a rare, perhaps a singular, appearance. The interior of the crystals was of the usual white colour, but the surface to the depth of a line or more was of a clear dark brown, graduating into the white, but not from the effect of decomposition. As the collection of crystals consisted only of the variously facetted summits of prisms, in which trapezoidal and rhomboidal figures prevailed, the specimen bore a strong resemblance to a mass of crystallized garnet.

Adularia.—This mineral is of still more rare occurrence in Scotland than the preceding. The very small specimens which I procured, were found in the same cavities with the felspar, and consisted of quadrangular prisms with terminations variously and irregularly facetted.

Garnet.—This mineral is so common in the schistose rocks of Scotland, that it is almost unnecessary to mention it as found at this particular place. It occurs both in the micaceous schist and in the hornblende schist; in which latter it is here very common, although by no means of very frequent occurrence in this rock in other situations. It is more worthy of remark, that it is often of a very pale reddish-white colour and granular fracture, much resembling certain varieties of granular quartz; and that, in some cases, it is so like, both in colour and texture, to the very compound schists in which it is imbedded, that it would not be suspected to exist if it was not detected by the wrathering of the rock, which leaves it projecting on the surface, where it is scarcely discoverable in the fresh fracture. There are few minerals which, with a steady geometric form, present so wide a range of aspect and composition.

Mica.—Independently of the common scaly form under which this substance occurs, in mixture with the ordinary rocks, I have found it, in the hills so often mentioned, under three distinct forms of crystallization, all of them more or less interesting, particularly as it is not often met with in this country in a detached and crystallized state.

It occurs imbedded in porphyry in the form of regular hexagonal prisms, about the tenth of an inch both in diameter and length: in all the specimens which I observed it is of a black colour. It is not very unusual to meet with it in porphyries, but it is rarely seen of so regular and perfect a form. Perhaps the most interesting circumstance attendant on this mica is the uniform direction of the crystals, the flat surfaces of the prisms all lying in parallel planes:—an occurrence which I have on other occasions noticed, both in ordinary porphyry veins and in veins of trap belonging to the most recent formations of that substance. A very important geological inference may be drawn from it respecting the disposition of the mica in those rocks which are supposed to owe their laminar structure to stratification. It is evident that this parallel disposition in gneiss and in micaceous schist, is not sufficient to prove that the mica has been mechanically deposited from a state of suspension; since, in rocks which from their venous form have unquestionably not been deposited in this manner, it equally holds a parallel arrangement. I may add that the parallelism of the mica in the porphyry veins, is conformable to the fissile tendency of the including rock, which, in all the cases that I have yet observed, is also parallel to the sides of the vein, even where that is at right angles with the surrounding strata, so as to leave no uncertainty respecting its truly venous character. There is no doubt that this universal parallelism, in crystals so numerous and so widely separated from each other, must depend on some common crystalline polarity; although we may be unable to explain this property, which is, however, no more obscure than every other phenomenon connected with crystallization. I have formerly pointed out analogous examples; and they are of frequent occurrence in cases where the phenomenon appears to have escaped notice, of which one of the most remarkable is that of graphic granite. In this it often happens that the same face of all the interrupted crystals of felspar through an extensive vein, is placed in the same direction: a fact easily examined in sunshine by taking reflections on various fractured points of the whole. I shall not here pursue this subject further;

but may remark that the same circumstance of uniformity in direction attends on the pinite formerly described.

Mica occurs also in the cavities of micaceous schist, crystallized at liberty. It forms extensive groups in these; being sometimes accompanied by a brown ochraceous powder, resulting, probably, from the decomposition of some mineral which cannot now be ascertained. The crystals are of an hexagonal form, and the prisms so short as to be mere scales. They vary from a quarter to one-sixth of an inch in diameter, and adhere to the stone, by their edges, so slightly, that they fall off in abundance in consequence of the jarring of the hammer. Their colour is silvery-white.

Chlorite.—This mineral occurs here in two modes.

It is found together with titanite, as already mentioned, in cavities in micaceous schist, forming irregular nodules; and also occupies similar situations in a blue schistose limestone, when it is generally accompanied by crystallized carbonate of lime. In one place it was found of a bright golden-yellow colour, with a perfectly metallic lustre; this effect appearing to arise from an incipient decomposition, although the specimen had lost nothing of its original firmness.

The next variety of this mineral is more remarkable, and, like the mica above mentioned, it is found in cavities in micaceous schist, sometimes accompanied by crystallized felspar. The crystals are crowded together, so as to confuse each other's forms in some cases; in others they are so independent as to be easily examined. When most perfect, the form is a very short hexagonal prism, terminated in each end by an obtuse hexagonal pyramid, of which the apex is truncated: the surfaces are almost always striated by fine lines indicating the direction of the scales into which the crystal is separable. Occasionally the prism is followed by a succession of two or more pyramidal frusta, each in order more obtuse than the preceding. In other instances the sides of the prism and of the corresponding pyramids become curved; and thus the crystals assume a spheroidal shape. When broken, in these cases, they are often found to consist of triangular laminæ radiating from a centre; so that the external figure is not formed, as would at first be supposed, by a succession of plates varying in size and parallel to the original prism. The colour of this variety is a dark green, and the ordinary dimension of the crystals is half an inch.

I must here add, that in the porphyry veins, which contain both pinite and mica, there is sometimes found a mineral which I am at a loss to name; since it cannot be referred to any of the known varieties of either substance. It is crystallized, like these, in hexagonal scales, which also maintain a general parallelism, and are about the tenth of an inch in diameter; but is distinguished from mica by its softness and want of elasticity, and from pinite, by its lustre, which is perfectly metallic. As mineralogists have recently found reason to suspect that the term mica comprises some varieties or species essentially distinct in some important points, it is not improbable that this also may be a distinct substance requiring an appropriate name.

Calcedony.—Although this mineral is of common occurrence, I have never hitherto observed it in the rock in which it is here found; namely, in micaceous schist. It does not occupy a vein, but occurs in slender rifts in the stone; covering the surface with flattish botryoidal protuberances.

Actinolite.—This is found in many of the rocks about Glen Tilt in considerable abundance. It is not uncommon in the gneiss, in which it generally forms a lamina more or less continuous; thus usurping the place of hornblende. The crystals, in this case, are of considerable dimensions. It occurs also in veins of pink carbonate of lime which traverse gneiss in the Banavie, and not far from the termination of the valley. Here it is fibrous, commonly radiated from various centres, and of a light-green colour; forming an ornamental contrast with the red hue of the substance in which it is imbedded. Lastly, it enters, in minute crystals, into the composition of a stratum of granular limestone of the same colour; producing also a very ornamental variety of marble, but which is in too small quantity to be applicable to any useful purposes.

Calcareous Spar.—To the instances of the occurrence of this substance formerly mentioned, I may add the following:

Veins and nodules of a bright ochre-yellow and crystallized carbonate of lime, occur occasionally among the blue limestone; the concretions being of large size and of a large platy fracture. Being sometimes irregularly intermixed with the blue basis, and with veins of white carbonate, they are often capable of being cut and polished into very ornamental marbles. They are not, however, sufficiently abundant to possess any value in an œconomical view.

In some of the schistose beds there occur small strata of white and yellow granular carbonate, the grains of which equal the size of the seeds of a pomegranate; and as they impress each other in a similar manner, this comparison conveys the best idea that can be given of them.

Perfectly formed crystals of calcareous spar are rare in this place; but I have recently observed the two varieties known by the name of the dog-tooth and the nail-head, together with the primitive rhomb.

Disthene.—This is the last of the substances which I have discovered in Glen Tilt since my original paper was drawn up, and with it I shall close these miscellaneous remarks. It occurs in a vein of quartz traversing micaceous schist, in two different places. In one, it is of its most ordinary blue colour; in the other, of a pearl gray. It is imbedded in the quartz; but one end of the prism is invariably fixed in the schist in which the vein is contained. Otherwise, it presents no peculiarity requiring a detailed notice.

VI.—*On the Geology of the Coast of France, and of the inland Country adjoining; from Fecamp, Department de la Seine Inferieure, to St. Vaast, Department de la Manche.*

By H. T. De la Beche, Esq. F.R.S. F.L.S. & M.G.S.

[Read November 2, 1821.]

THE bay included between Cap d'Antifer to the east, and the Pointe de Barfleur on the west, is about sixty English miles in breadth*: it is formed by part of the coast of the department of the Seine Inferieure, the whole coast of that of Calvados, and the eastern part of the coast of La Manche.

The shore of the department of the Seine Inferieure is bold; generally from four to five hundred feet in height†; and it is intersected by narrow valleys, which do not in general run far inland. This line of high bold coast ends near Cap la Hêve. The right bank of the Seine, for many miles into the interior, is, with the exception of the low land between Havre and Harfleur, high and perpendicular: the left bank, from Villerville sur Mer‡ till about eleven miles east from Honfleur, is formed by high hills, which present at their bases either low cliffs or alluvial plains. The remainder of the left bank of the Seine is precipitous.

From Henqueville to Dives the coast is hilly, with the exception of two flat sandy plains; one about a mile in length, between the river Toucques and Benerville Hill; the other, three miles long, between Benerville Hill and Villers sur Mer. This hilly country is separated from the low land of the environs of Caen by a line passing from the mouth of the river Dives, in a south-east direction, through Etréez.

From Dives to St. Come, about twenty miles distant, the coast is in general flat and sandy; there are however some low cliffs, ten or fifteen feet in height, near Lyon sur Mer and Luc. The country rises into hills near St. Come; and

* See the Map, Plate XI.; and Sections, Plates IX. and X.

† The highest cliff is that which rises immediately to the eastward of the harbour at Fecamp.

‡ A village about four miles west from Honfleur.

the cliffs, which commence a little to the westward of the village, continue nearly to Grand Camp, where the shore is again sandy and flat. This flat and sandy coast extends nearly to Carentan, backed however by low hills at the point of land which separates the marshy flat of Carentan from the mouth of the Vire.

From near Carentan to St. Vaast (about twenty miles) there are no cliffs; a marshy flat, which varies in breadth from a quarter of a mile to a mile and a half, separates the hilly country from the sandy dunes, which here form the shore.

The coast, for some distance to the north of St. Vaast towards Barfleur, is formed by a low granite plain, covered in a great measure with sand near the sea. The hills, which back the flat coast between Fontenay and St. Vaast, are of considerable elevation.

Such is the physical appearance of the coast. I shall now proceed to detail its geological characters, beginning with the upper rocks.

Chalk.

The cliffs from Fecamp to Cap d'Antifer are composed of chalk with flints, containing the same fossils as in England. From Cap d'Antifer to the Chateau d'Orchet, within the mouth of the Seine, the upper part only of the cliff is chalk, the lower being green sand. At the latter place the green sand disappears, and the chalk again forms the entire cliffs, but near its junction with the green sand, contains particles of that substance.

The portion of the department of the Seine Inferieure bounded by the seacoast, the river Seine, and a straight line drawn from Fecamp to Caudebec, is composed of chalk, covered generally by flint gravel. The chalk abounds in flints, which sometimes form seams of three or four inches in thickness.

On the left bank of the Seine also the chalk caps the hills at Fiquefleur, at Honfleur, and at Henqueville, resting upon green sand.

It would be difficult to give a correct idea of the line of hills capped by chalk, on the outskirts of the great chalk formation, without a good physical map of this part of France, which I believe does not exist. The main body of chalk may be said to cross the Seine between Honfleur and Fiquefleur, and to be continued in a line, passing about midway between Pont Audemer and Pont l'Eveque; whence passing to the west of Cormeilles, it crosses the road from Lisieux to Paris, in a south-east direction, between L'Hotellerie and Duranville.

The chalk throughout this tract, which forms a high table land, is for the most part concealed by flint gravel*, generally angular, and sometimes forming beds exceeding one hundred feet in thickness.

The valley of the Rille, from Pont Audemer to Brionne, affords a distinct section of the chalk with its thick coating of gravel beds. At Brionne this rock contains very few flints, and it is equally destitute of them at Cormeilles, on the banks of the river Calone. The strata of the whole body of chalk have a gentle inclination to the E.N.E. The surface occasionally presents great inequalities, assuming the form of pyramids or needles†, &c.

Green Sand, and Iron Sand.

Green sand appears under the chalk at Cap d'Antifer, and forms the lower part of the cliffs as far as Cauville, where marl, containing green earth, may be observed under it. From thence to Cap la Hêve the shore is encumbered by fallen masses of chalk and green sand. At Cap la Hêve this thin marl bed is again seen beneath the green sand. It rests upon iron sand, containing mica and siliceous grains, which are sometimes as large as peas; and this again upon blue marl and marlstone.

Between Cap d'Antifer and Cauville the green sand contains numerous Alcyonia, several varieties of Echini, Ostrea crista-galli (Parkinson), Turrilites costata‡, Ammonites Goodhallii, &c. At the Vaches Noires it abounds with fossils, one of the most remarkable of which is, the Hallirhoa costata§ of M. Lamouroux.

At Henqueville Cliff, on the south of the Seine, the green sand is again

* The farmers occasionally sink pits through the gravel, when not very thick, in order to obtain the chalk.

† In England also, at Dunscombe Hill and Quarry, on the coast of Devonshire, the cliffs exhibit a few detached portions of chalk, ten or twenty feet in height, resting upon green sand and covered by unrolled flint-gravel.

‡ The names of fossil shells throughout the remainder of this communication, are those given in Sowerby's Mineral Conchology.

§ Exposition Méthodique des Genres de l'Ordre des Polypiers. Paris 1821.—M. Lamouroux appears to have been led into error with regard to the rock at the Vaches Noires, in which these fossils are found: their locality is in the green sand, and not the blue clay (Oxford clay) beneath it. The green sand is continually falling down, and in consequence its fossils frequently become imbedded in the soft clay at the base of the cliff.—Fig. 5. Plate IX. shows the interior structure of these fossils; which are found also in the green sand of Warminster in Wiltshire.

found between the chalk and the blue marl and marlstone: I did not observe any iron sand at that place.

To the westward of Henqueville, the next hill, at Benerville, has no green sand, its summit being formed of coral rag: but the cliff between Villers sur Mer and Dives, usually called the Vaches Noires*, is capped by it; the green sand resting partly upon coral rag, and partly upon beds of oolite, above a thick blue clay (Oxford clay).

The green sand formation does not appear upon the coast to the west of the Vaches Noires, but it extends inland along the upper part of the hills from Trouville sur Mer. Along this tract however it loses the usual character of this bed, the prevailing rock being a loose siliceous sand with nodules of blue limestone or chert disposed in layers. At the subterranean quarries near Lisieux, a shaft is cut through this rock to a thick bed of whitish soft calcareous sandstone, under which is another bed of siliceous sandstone with nodules of limestone and chert; the whole rests upon oolite, as may be seen at the bottom of the valley between Lisieux and Glos. Near the latter place there is a quarry, at the top of which a loose siliceous and ferruginous sand presents itself, containing large nodules of gray siliceous sandstone; to this succeeds siliceous sandstone containing organic remains; then a stratum, nine inches thick, of compact gray limestone; and under it a siliceous sandstone bed, which rests upon a large-grained oolite.

The hilly country, comprehended between the chalk district and a line drawn south-east from Dives to Etréez, is composed of green sand, resting either upon the marl and marlstone which forms the base of Cap la Hêve, or upon some member of the oolite formation. But many beds of the green sand formation, which occur inland, do not extend to the coast.

Blue Marl and Marlstone.

This formation, which has been mistaken for lias, from its general resemblance to that rock, contains fossil crocodiles† at Havre, and near Cap la Hêve a bed of oysters. These, with the exception of an imperfect cast of an univalve,

* The name Vaches Noires is properly applied only to the large fallen blocks, blackened by sea-weed: these blocks are very dangerous to coasting vessels.

† M. Cuvier, who has described these remains, has been misinformed in the statement, that the *same* marl extends under the Vaches Noires cliffs; for between the latter and the Havre marl there occur several members of the oolite formation, such as thick beds of coral rag, oolite, &c. as may be observed at Henqueville cliff, and at the hill between the river Toucques and Benerville.

and another of a bivalve, were all the organic remains that I observed in it. It is first seen at Cap la Hêve dipping gently to the east: and it forms the flat upon which Havre is built*. At Honfleur it may occasionally be discovered amid the fallen masses of chalk and green sand; and at Henqueville it forms a bed a hundred and fifty feet thick interposed between green sand and oolite, but it is not seen further to the west.

Oolite Formation.

I include under this head the series of rocks, which begins with the Portland beds, and ends with the inferior oolite.

Portland Beds.—At Henqueville cliff may be traced thin beds of a hard yellowish-white limestone, which contain seams and nodules of chert, and casts of fossil shells, the same with those which are observable in the Portland beds; these rest upon coral rag. They are however much concealed by the fall of the superincumbent beds; and I was not fortunate enough to meet with them in the interior.

Coral Rag.—This rock, accompanied by calcareous grit, first appears on the east of Henqueville cliff, of which it forms the lower part. Proceeding westward, it forms the top of the hill between the river Toucques and Benerville, and thins off upon the eastern part of the Vaches Noires cliffs. Near Villers sur Mer it contains a vast quantity of corals and Echini.

Oolite and Blue Clay.—The latter is first seen on the coast forming the lower part of the hill between the Toucques and Benerville. In this place the beds of calcareous sandstone and oolite, which are to be seen between the coral rag and blue clay at the next hill to the westward (the Vaches Noires cliffs), are not exposed to view; but as the summit of the hill is composed of coral rag, there can be little doubt of their existence.

The Vaches Noires cliffs afford an excellent section of these rocks. The coral rag and calcareous grit thin off, as before stated, on the east: under these is found a whitish marl; then a bed of oolite about four feet thick; then blue marl or clay. This last is about three hundred feet in thickness, and agrees in its geological position with the Oxford clay: it contains septaria, and a few thin beds of grayish limestone; and among its fossils are the following:—

* At Havre the marl is used for making tiles and bricks.

A fossil crocodile, described by Cuvier,	Ammonites biarmatus,
Bones of the Plesiosaurus,	——— sublævis,
A fossil fish,	——— communis,
An Encrinite,	——— omphaloides,
Trigonia clavellata,	——— excavatus,
Gryphæa dilatata,	Perna aviculoides,
Nautilus sinuatus,	Modiola ———
An undescribed Ammonite (Pl. IX. fig. 4.)	Ostrea ; two species.—&c.

This blue clay forms the whole of the hill to the west of the Vaches Noires, after which it is seen no more on the coast; but the base of the hills, extending in a south-east direction from Dives to Etréez, is composed of it. The hill rising eastward of Etréez affords the same section as the west end of the Vaches Noires cliffs.

The low sandy coast which succeeds, to the westward of the hills at Dives, conceals the rock upon which the blue clay of the Vaches Noires rests. The best section that I obtained in illustration of the order of the beds, was on the road from Caen to Etréez, where the blue clay rests upon a yellowish calcareous sand with sandstone, in alternating layers (cornbrash). The clay appears to form the bed of the Dives river, to the westward of which is a low chain, running south-east parallel to the high range, and principally composed of blue clay, or of calcareous sand and sandstone. West of the low range the country is nearly level to Caen.

Cornbrash.—Of this I observed but little. The hill behind Moull, on the road from Caen to Lisieux, is composed of a yellow calcareous sand and sandstone resembling cornbrash, upon which the blue clay (Oxford clay) appears to rest; and the latter is afterwards met with on the road to Etréez. The hard strata are quarried at Moull.

No cornbrash limestone appears on the coast: the part at which it ought to occur, between Dives and Sallenelles, is concealed by sand and marsh-land.

Forest Marble.—Beneath the calcareous sand and sandstone, and above the freestone of Caen, is a calcareous rock, sometimes rather oolitic, composed in a great measure of broken shells, and containing very small fossil corals; from which last circumstance it has obtained from M. Lamouroux, in his Exposition Méthodique des Polypiers, the name of Calcaire Polypier. In geological position and structure this limestone resembles the forest marble. It occurs in the low cliffs at Luc and Lion, and probably along the whole coast from

Sallenelles to St. Come, though hid under the dunes. It appears likewise inland, between the range of Caen freestones and the low hills to the eastward; and at Cagny, on the road from Caen to Moull, there are quarries of this rock; as also at Bonneville, two leagues from Caen on the road to Troarn.

Caen Freestones.—These beds occupy the same geological position with the freestones of Bath; they are not however oolitic, but sandy. When first quarried they are friable and soft, but become harder by exposure to the atmosphere. The beds are not observable on the coast, and from the general flatness of the country the line of separation between them and the rocks above and below is rather difficult to trace. The principal quarries are in the neighbourhood of Caen, and along the banks of the Orne from that town to Sallenelles. The freestones of Caen were, as is well known, formerly much used in England.

On the road from Caen to Bayeux the freestone beds may be traced in continuity as far as St. Croix: they extend, on the road from Caen to Villers, nearly to Tourville*; on the road from Caen to Condé sur Noireau, to Fontenay; and on that from Caen to Falaise nearly to the latter town †; for I am disposed to consider the quarries at St. Pierre and Aubigny as the lower of these beds.

In that part of the department of Calvados which is principally composed of these beds, older rocks frequently present themselves. The country on the road from Caen to Falaise is composed of the freestone beds as far as Cintaux, where suddenly, without any difference in the level of the surface, a compact siliceous sandstone rises from under them, which continues nearly to Langannerie; from thence the calcareous beds continue to Potigny, where a small area is again occupied by a bed of quartz rock.

On the road from Caen to Villers argillaceous slate and quartz rock are disclosed by denudation at Tourville; and at May, on the road from Caen to Condé sur Noireau, there is a denudation of a sandstone that has much the appearance of old red sandstone.

Inferior Oolite.—In the department of Calvados, the remarkable bed of this rock with ferruginous grains, is accompanied, both above and beneath,

* I am informed that they are also found to the south of the denudation at Tourville.

† The Caen freestones are also found beyond Falaise; but that part of the country does not come within the scope of the present communication.

by a calcareous sandstone, varying in colour from yellow to white, and containing seams and nodules of chert and flint.

I have not observed this bed with ferruginous grains on the coast; but the calcareous sandstone with cherty seams caps the lias cliffs from St. Come to St. Laurent. From St. Come to St. Honorine the beds rise gradually to the westward; but at the latter place the strata dip to the N.N.W. and in consequence the lias is soon lost under the sea; and the cliffs from Vierville to Grand Camp are composed almost entirely of the calcareous sandstone with seams of chert.

The inferior oolite may be traced inland from between Maisy and Isigny, south-eastward, to a small hamlet (on the southern margin of the map) between Falaise and Pont d'Ouilly: the line of junction with the older rocks winds considerably. The oolitic strata rest upon lias from between Maisy and Isigny to within a short distance from Bayeux. At Veaucelle, near the latter town, they repose upon quartzose gravel beds of the new red sandstone formation; the bed with ferruginous grains is here seen accompanied by calcareous sandstone, containing seams of flint, and it also appears in some quarries about a mile north-east from Bayeux; but the flint occurs there not in seams but in rounded nodules.

This bed with ferruginous grains contains an abundance of fossils, almost entirely resembling those found in the same rock in the south-western parts of England, particularly at Dundry Hill, near Bristol. Among those which I obtained at Bayeux were the following:—

Nautilus ———.	Ammonites annulatus.
Ammonites Brocchii.	——— Greenovii.
——— Braikenridgii.	Melanea lineata.
——— Brongniartii.	Trochus fasciatus.
——— Gervillii.	Astarte ———.

&c. &c.*

From Bayeux to about three or four miles eastward of Villers the inferior oolite rests upon lias; from thence to Croisy (a little hamlet on the road from Condé sur Noireau to Caen) it rests upon argillaceous slate and grauwacke. At Croisy the rocks of this formation are remarkably white, so that the calcareous beds with flints very much resemble chalk. The appearance is more

* For a more complete catalogue than I had an opportunity of making, see De Gerville, Journal de Physique, Tom. lxxix. page 22, Catalogue D; and Tom. lxxxiv. page 208, Catalogue D.

striking, from the flints being black and disposed in regular layers; they have not, however, such irregular shapes as the true chalk flints. Even the bed with ferruginous grains, which is here exposed between the other beds, has, in one of the quarries, a white base. Its fossils agree with those in the same bed at Bayeux.

From Croisy, in a S.S.E. direction, to a small hamlet on the road from Falaise to Pont d'Ouilly, the inferior oolite beds rest upon argillaceous slate and grauwacke.

The beds of the inferior oolite may in general be traced by a superficial bed of unrolled angular gravel, composed either of flint or chert; as the one or the other predominates in the oolitic beds of the vicinity. This is particularly remarkable upon the edges of the beds where they rest upon the slate: and on the road from Falaise to Pont d'Ouilly the slate itself is, in several places on the high ground, covered by this kind of gravel, the debris most probably of the inferior oolite beds which once rested upon it. There is a great deal of this gravel between the little hamlet of St. Basille and Tilly sur Seule.

At St. Laurent de Condel a red porphyritic conglomerate is exposed by the removal of the inferior oolite, which appears at one time to have covered it. The quartz rock and slate of Falaise are also disclosed by a denudation among the same beds; and there may be many other instances of denudation on the outskirts of the slate hills.

Lias.

The lias first appears eastward on the coast of the department of Calvados, between St. Come and Arromanche, under the calcareous sandstone with chert seams above described; from thence to St. Honorine it forms the lower part of the cliffs, gradually rising to the west. At St. Honorine this stratum forms a great curve, and, dipping N.N.W., disappears on the shore to the west of St. Laurent. Near Port en Bessin it extends to some distance inland, and at the Fosse du Souci, about half a league from that place, the rivers Drome and Aure find a subterraneous passage through it; reappearing on the coast near Port en Bessin, in the form of large springs or fountains.

The boundary of the lias in the department of Calvados will be best understood by reference to the accompanying map, as the lines which separate it from the rocks above and beneath wind very considerably. Its general direction is south-east from Isigny to Villers. It is extensively quarried along the line that separates it from the older rocks, being much used for agricultural and other purposes. It rests upon the new red sandstone formation from Isigny to Villers, and, eastward of the latter place, a small portion is to be traced resting upon argillaceous slate, until it is hid under the inferior oolite.

Lias, reposing upon new red sandstone, forms the northern part of the point of land between Carentan and Isigny, and is there separated from the sea by a marshy and sandy flat. From the vicinity of Carentan to Fontenay it forms the elevated ground behind the marshy flat which there also separates the hills from the sea, and extends a considerable distance into the interior of this part of the department of La Manche.

Blue lias occurs at Ivetot, about three-quarters of a league from Valognes, on the road to Briequebec, under a calcareous rock to be mentioned hereafter. It is probable that from the vicinity of Carentan nearly to Montebourg it rests upon the new red sandstone formation; and it does so between Lestre and Montebourg, and at Negreville, on the road from Valognes to Briequebec. At Brevans, north-east of Carentan, it occurs above red sandstone. From near Bayeux to Villers it rests upon beds of quartz gravel.

The lias of this part of France exactly resembles that of the south of England; containing, as in England, an abundance of the Gryphæa incurva and Plagiostoma gigantea, with ammonites and belemnites*. I have little doubt, from the information of the quarrymen, that the remains of the Ichthyosaurus are occasionally found in it, particularly at Brevans.

The white and blue strata are in general much intermixed: between Port en Bessin and St. Honorine white lias of considerable thickness forms the base of the cliff.

There is a fault in the lias west of Port en Bessin, which runs across two small headlands.

New Red Sandstone Formation.

No member of this formation appears on the coast within the tract at present under consideration, with the exception of some quartzose gravel beds near Lestre (departement de la Manche), which are however separated by a marshy and sandy flat from the sea.

In the department of Calvados there is very little new red sandstone or red marl, except in the neighbourhood of Lison, where the elevated ground upon

* This lias district is described very accurately, together with its fossils, by M. de Gerville. See Journal de Physique, Tom. lxxix. pages 18, 19, 20, and 21, Catalogues B and C; and Tom. lxxxiv. pages 209 and 210, Catalogues B and C.

which the forest stands is composed of both. From Lison towards Isigny there is much red marl mixed with the gravel beds, and the same rock is seen also at the bridge over the Vire near Isigny.

Gravel formed of rounded quartz pebbles is in Calvados the principal member of this formation: it is associated with sand, generally whitish, seldom red, and occasionally with red marl; the pebbles are rarely cemented, as in the new red sandstone conglomerate of the coast of Devonshire.

In the department of La Manche the new red sandstone formation occurs abundantly in the neighbourhood, and to the east and south-east of Carentan; the road from St. Lo to the latter place affording a good section. It rests, near St. Jean Day, upon argillaceous slate; thence to Carentan the country is composed of red marl and red sandstone, mixed with the usual blue and white strata.

The gravel beds so common in the department of Calvados are more rare in this part of the department of La Manche.

Near Brevans and Cats, on the point of land between Isigny and Carentan, the new red sandstone is yellowish, mixed with red and grey, and is tolerably compact. From Carentan to Sainteny, and towards Beaute, beds of gravel and sand occur; but the sand is seldom red.

The gravel beds above mentioned occur between Lestre and Montebourg. From Valognes, on the road to St. Vaast, the gravel beds, red marl, and red sandstone, form the country as far as a little hamlet on the river Sinope, where the sandstone is seen to rest upon argillaceous slate. On the top of the next hill towards St. Vaast, gravel beds, altogether about thirty feet in thickness, rest upon porphyritic conglomerate and argillaceous slate; and the same thing occurs at two or three other places further on the road.

In the department of Calvados this formation rests upon argillaceous slate and grauwacke; except at Litry, where it rests upon coal measures. In the department of La Manche, at Lestre, Montebourg, and in the neighbourhood of Valognes, it rests upon quartz rock; of which substance the gravel beds so often mentioned are in fact principally, if not wholly, composed. This may also be the case (though concealed by lias and the oolites) in the department of Calvados, where the quartzose gravel is most abundant. That the quartz rock occurs beneath the red sandstone formation, is seen at the several denudations.

Porphyritic Conglomerate.

This rock constitutes the summit of the Bruyere de Crecy, a mountain near Condé sur Noireau. It is composed of rounded quartz nodules, varying in size from that of a pea to three or four inches in diameter, and agglutinated by a hard red argillo-siliceous cement, in which are small crystals of felspar. I did not perceive that it was stratified: it appears to rest upon nearly vertical strata of argillaceous slate and grauwacke.

A similar rock occurs at St. Laurent de Condel on the same road, under oolite, and is exposed to view in one part of the high ground between Valognes and St. Vaast, though generally concealed by the gravel beds. This porphyritic conglomerate bears a striking resemblance to that which occurs under the same circumstances in the neighbourhood of Exeter.

Coal Measures.

These strata are found at Litry, E.S.E. of Bayeux*, extending about 1700 yards from east to west, and 850 yards from north to south; their direction is east and west, and their dip 22° to the north. Some of the coal beds are of tolerable thickness; they vary much in quality, and are not in general very good. They rest upon argillaceous slate.

Old Red Sandstone.

I am inclined to refer to this formation the compact sandstone found at May, between Caen and St. Laurent de Condel. It rests upon what is usually termed transition limestone, and with it is exposed to view by a large denudation in the oolite formation. This sandstone is either white, red, or blueish; its beds vary in thickness, and are sometimes micaceous; their dip is about 45° to the north; they are extensively wrought for paving and flag stones.

The sandstone which rests on quartz rock between Cintaux and Langannerie, on the road from Caen to Falaise, may be a continuation of the May beds.

Compact Limestone with Slate.

A small portion of these substances occurs under the sandstone near May; the limestone is very compact, and in beds two or three feet thick, between which are thin beds of slate. I did not observe any organic remains in it;

* See Journal des Mines, Tom. xii. page 346.

but the whole had the appearance of what is usually termed transition limestone. I understand that it was formerly quarried as marble, for which it is well adapted *.

Quartz Rock.

The quartz rock, in the departments of Calvados and La Manche, varies from red to whitish-grey and white: it is difficult to obtain specimens, owing to its toughness. It occurs generally in the form of a sandstone, but passes in some instances into quartz; and is found in beds from two to eight feet in thickness, sometimes rather contorted, and frequently traversed by veins of quartz. The quartz rock of the department of La Manche is described at length by M. Brongniart in his memoir on the Cotentin, and named by him *Quartz grenu*†. The rocks exposed by the denudations in the oolite formation, in the department of Calvados, are formed either wholly or in part of quartz.

At Grouvy, a short distance from Langannerie already mentioned, this substance forms rough and precipitous ground, which rises above a small river: the colour of the rock varies from grey to red; the beds are from two to four feet thick, and dip at about an angle of 80° to the south. Among them is a bed of iron ore about two feet thick, having the same dip and direction as the rest: and when I was there, several heaps of it had been collected, but I am not aware that it has as yet been smelted. These quartz beds continue to Urville.

At Potigny, on the road from Caen to Falaise, the same rock is exposed by denudation, at the entrance of the village, in beds which are highly inclined, and covered by horizontal strata of oolite.

The eminence upon which stands the castle at Falaise (the birth-place of William the Conqueror), and the picturesque cliff opposite to it, are composed of very compact quartz rock. Upon the top of the hill leading out of Falaise, on the road to Condé sur Noireau, similar beds occur: they are separated from those on which the castle stands by argillaceous slate.

Between Tourville and Mondrainville, on the road from Caen to Villers, argillaceous slate and grauwacke rest upon quartz rock: the beds all dip at an angle of about 45° or 50° to the north, and form part of a space exposed by

* I am informed that this limestone is quarried very extensively in that part of Calvados which is beyond the limits of the present map; and that in character it approaches nearer to the Dudley limestone than any other. Its fossils have been enumerated by M. De Gerville.

† Journal des Mines, Tom. xxxv.

a denudation in the oolite formation. The relative position of the quartz rock and argillaceous slate between Mondrainville and Tourville and at Falaise, would lead to the conclusion that they alternate here, as they do between Valognes and Cherbourg. The general character of the slate is well displayed at the mountain of Le Roule behind the last-mentioned town; where it varies from red to grey, the grey being often as compact as quartz; the beds are sometimes several feet in thickness, and frequently curved; their dip is between 45° and 50° to the north. I observed in the quartz rock of Le Roule the cylindrical bodies mentioned by Dr. McCulloch as occurring in the quartz rock of Glen Tilt *. On that part of the hill over which the road to Valognes passes, about a league and a half from that place, the quartz rock alternates with argillaceous slate.

There is much quartz rock in the vicinity of the latter town; it constitutes the high hill between Valognes and Montebourg; on the top its beds are nearly white. At the high hill between Lestre and Montebourg, which is also composed of it, the beds are mostly grey, sometimes red; they vary considerably in thickness, and dip to the east at about an angle of 45°; the same beds continue to Greneville (on the coast between St. Vaast and Lestre), where they probably rest upon argillaceous slate.

Near Negreville, on the road from Valognes to Briequebec, and from thence to the latter town, a series of rocks occurs, which may generally be referred to quartz rock, but which, in part, very much resemble old red sandstone, being micaceous, and of the usual colours and character of that rock: this sandstone (if really such, and not a variety of quartz rock) either alternates with or passes into quartz rock †.

The direction of the beds near Negreville is from E.N.E. to W.S.W.; their dip is to the E.S.E. at about an angle of 80°.

At the mountain of Le Roule, and at the high ground between Lestre and Montebourg, thin beds of sandstone, which are in general red, slaty, and not very compact, occur in the quartz rock.

Argillaceous Slate and Grauwacke.

A considerable portion of the south-western part of the department of Calvados is formed of these rocks, which are continued into the department of

* Geological Transactions, Vol. iv. p. 269.

† Dr. McCulloch mentions an alternation of old red sandstone with quartz rock, as occurring in the Isle of Sky. Geological Transactions, Vol. iv. p. 273.

La Manche. Their boundary line would pass nearly west from the neighbourhood of Perriers to Litry, thence S.E. to Villers *, and thence E.S.E. to Croisy, from whence it passes S.E., and crosses the road from Pont d'Ouilly to Falaise at a little hamlet half way between the two places.

The grauwacke, though not very abundant, may be observed in several places: at the little hamlet last mentioned it is visible in beds among the slate, which are highly inclined, and have a direction about east and west.

From Condé sur Noireau to the Bruyere de Crecy the slate is disposed vertically in an east and west direction; grauwacke is observable on the northern side of the latter, and may occasionally be seen among the slate from thence to Croisy; the beds are sometimes curved; their general dip is at an angle of about 45° to the north.

At Jurigny this slate forms a small tract of country which is surrounded by quartzose gravel beds of the new red sandstone formation.

The slate near St. Lo is precisely that of the country round Condé sur Noireau, Pont d'Ouilly, Villers, &c., and is accompanied occasionally by grauwacke.

The slate of the north of La Manche appears to be the same as that in Calvados; near Cherbourg and Valognes, and in the denudations at Falaise and Tourville near Caen, it is associated with quartz rock, which, as well as the slate, is alike at both places.

Near St. Vaast the slate hills end suddenly upon the low granite plain which extends towards Barfleur. The slate hills on the south-west of Calvados and the adjoining portion of La Manche attain considerable elevation.

Granite.

The granite that comes within the scope of the present communication, is that which is seen a little above high-water mark at St. Vaast and Reville (department of La Manche), and forms a plain at the termination of the slate hills. The granite of Reville generally resembles that of Dartmoor; and, like it, occasionally contains crystals of felspar as much as two inches in length. This granite varies from grey to a light red tint, according to the colour of the felspar. I saw no other extraneous mineral in it but tourmaline in small crystals, and even these were rare.

The granite of the coast near Reville splits in two directions; one east and

* Roofing slate has been quarried at Villers.

west, the other north and south; and forms large rhomboidal blocks: some few groups of granite rocks on the shore are split into similar blocks, which have not the same direction.

The granite at St. Vaast and the opposite island of Tatihou * is somewhat different from that of Reville, though evidently in connection with it; it is split into similar blocks, and the fissures are in the same direction with those at Reville; in both places it is traversed by granite veins, of which the predominant ingredient is flesh-coloured felspar.

At high water the granite near Reville is only seen here and there, being nearly covered up by sea sand; but at low water it is more exposed to view. Near Reville a little gneiss may be observed on the beach.

Grey granite occurs at St. Honorine, a short distance S.E. from Condé sur Noireau (department of Calvados); probably part of the same bed that is found in the neighbourhood of Vire.

In addition to the rocks already noticed in the present paper, is one which ought properly to have been placed before the chalk, as it most probably belongs to the tertiary formation. It occurs at Freuville, between Valognes and Carentan, and consists of a tolerably hard light-coloured limestone, containing an abundance of fossil shells, particularly bacculites. I observed it only at one quarry near the village, and I imagine that it rests upon lias, which occupies the surrounding country †.

Another limestone, about the place of which in the series I was not altogether satisfied, is found at Valognes: its boundaries and fossils have been ably described by M. de Gerville ‡. It is of a light colour, contains many fossils, and extends from Ivetot, in a northern direction, to St. Germain.

At St. Laurent on the coast of Calvados there is a submarine forest upon lias clay, where the remains of trees are very numerous §; and there are also traces of another on the Vaches Noires clay, between Benerville and Villers sur Mer. In neither of these instances can any subsidence be discovered or surmised.

* The sands between St. Vaast and Tatihou are dry at low water, and may be crossed on foot or horseback.

† For a more particular account of the tertiary beds of this part of France consult M. de Gerville's Memoirs, in the Journal de Physique (Tomes lxxix. and lxxxiv.), in which will be found very complete Catalogues of their fossils.

‡ Journal de Physique, Tom. lxxix p. 26, Catalogue G; and Tom. lxxxiv. p. 211, Catalogue G.

§ Its appearance much resembles that on the north coast of Somersetshire described by Mr. Horner. See Geological Transactions, Vol. iii. pp. 380, &c.

It will be seen from the preceding observations that, with the exception of quartz rock, the rocks described in this communication nearly correspond in position, structure, and organic remains, with those found in the southern parts of England; of which they are most probably the continuation. The chalk which forms the coast of the department of the Seine Inférieure seems to be a prolongation of that of the Isle of Wight and Dorsetshire. The same may be said of the green sand;—which in Devon and Dorset covers in succession oolite, lias, and new red sandstone, the intermediate rocks being wanting; and which in Calvados rests in succession upon several members of the oolite formation. The oolites and lias of Calvados are probably the same as those of Weymouth, Bridport, and Lyme. The new red sandstone of Calvados and La Manche agrees in position, though not always in appearance, with the same rock in Devon. The porphyritic conglomerate of the Bruyere de Crecy and St. Laurent de Condel bear a striking resemblance to that near Exeter; and the slate of Calvados and La Manche is probably prolonged into Devonshire.

The incorrectness of the once popular notion that England has been torn from France by some sudden violence, has already been exposed by Mr. W. Phillips * and others. It is much more reasonable to suppose that the bed of the English channel was formed at the same time, and in the same manner, with those differences of level which are observable every where on dry land. The depression that forms the bed of the English channel is very trifling in proportion to its extent of surface; and is very much exceeded in depth by the large continental lakes. The greatest observed depth of water at the western extremity of the channel, between the Land's End and Ushant, is only seventy fathoms, the distance between the two places being about thirty leagues †; whereas the Lake of Geneva is nearly double that depth between Lausanne and Evian, the distance between the two latter places being only about three leagues. The greatest depth of water in the narrowest part of the channel, between Dover and Cap Blanc Nez, is thirty fathoms, the distance six leagues; and between Cap La Hogue and the Isle of Portland, a distance of about sixteen leagues, the depth of water is only forty-five fathoms, or two hundred and seventy feet.

* In his examination of the cliffs on each side of the Dover Straits. Geol. Trans. Vol. v.

† Leagues, thirty to a degree.

VII.—*On a Fresh-water Formation in Hordwell Cliff, Hampshire; and on the subjacent Beds, from Hordwell to Muddiford.*

By T. WEBSTER, Secretary to the Geological Society.

[Read December 7, 1821.]

In the memoir which I presented to this Society in the year 1813 *, on the fresh-water formations of the Isle of Wight, I mentioned Hordwell Cliff as consisting of the London clay. I had not then had an opportunity of visiting the spot, but depended upon the descriptions of others.

So long ago as the year 1766, a work was published by Gustavus Brander, under the title of *Fossilia Hantoniensia*. It contained remarkably good engravings of a number of shells and other organic bodies, collected (as is stated in the preface) in the cliffs between Christchurch and Lymington in Hampshire; but chiefly near the village of Hordwell.

Some time since, the agreement observed between those fossils of Hampshire, and those of the London clay found at Highgate and other places, pointed out the identity of the beds from which they were derived; and it was by the same kind of agreement in the fossils, that I was enabled to show, (in the paper above referred to,) that the northernmost of the vertical beds at Alum Bay, in the Isle of Wight, corresponded generally to the London clay, but more especially to this bed near Hordwell which belongs to that formation; and, consequently, to establish the relative geognostic situations of the remaining vertical beds at Alum Bay, and also of the alternating fresh-water and marine strata.

But the proof, by which I endeavoured to establish the identity of the beds at Alum Bay and at Hordwell, resting almost entirely on the fossils, it was necessary, in the present advanced state of geological science, to have the additional evidence of other circumstances: and with the view of examining this subject still more closely, I have very lately again visited those places.

* Transactions of the Geological Society, Vol ii. p. 161.

In my former paper I observed, that from the proximity of Hordwell Cliff to Alum Bay and Headen Hill, it appeared to me very probable that some traces of the fresh-water formation, for which Headen is so remarkable, might be found at Hordwell. Indeed Woodward, whose valuable catalogue I have had frequent occasion to mention, speaks of fresh-water shells in a marly stone from Hordwell: but his theoretical opinions with respect to the causes which operated in burying these shells in the earth probably prevented him from examining the order of the beds; and it does not appear that he had been at the spot: nor was the agency of fresh-water in the formation of mineral beds at that time recognised.

I also stated, that I had received from Professor Buckland fresh-water shells sent from Hordwell; and I have seen such shells included in several collections of the Hordwell fossils: one of these, called by Dr. Solander Helix lenta, is figured in Brander's work. Notwithstanding these circumstances, however, it does not appear that any of the observers above enumerated were aware of the proper situation of these fresh-water shells; it being generally supposed, that they were found either mixed with Brander's marine fossils, or lying immediately over them without being in distinct beds; much less was it imagined that there existed an extensive and distinct fresh-water formation at Hordwell, such as I am about to describe. I am indebted to the Rev. Dr. Cooke, of Tortworth, for the first notice that traces of this formation were to be seen at Hordwell: but I have reason to believe that a regular examination and delineation of the instructive section formed by the coast has not hitherto been effected.

The portion of the coast of Hampshire, the description of which forms the subject of the present communication, extends from Hurst Castle, on the extremity of a bar in the Solent, to the village of Muddiford, one mile east of Christchurch*. From Hurst Castle to Muddiford is about ten miles. The narrow bar, which joins Hurst Castle to the land, is nearly two miles in length: it appears to have been produced by the rapid current, which, turning round Christchurch Head, and striking on Barton and Hordwell Cliffs, is deflected towards the Isle of Wight, before it enters the Solent in its course to the east. The bar consists of water-worn pebbles of chalk-flints, there called *shingles*: which may have been derived, in part, from the chalk cliffs of Dorsetshire and the Isle of Wight; and partly from a thick bed of diluvian gravel, which forms the upper portion of Hordwell Cliff, and which, continually falling, is washed away by the sea. The tide is very rapid between Hurst Castle and the Isle of

* See the Map and Section, Plate XII.

Wight, and, being thrown on the latter place, it is rapidly destroying the coast: but the north side of the Solent being defended from its action by the bar of shingles, an extensive deposition of mud, that has been carried down by the rivers and streams in this part of Hampshire, has taken place along that shore.

Where the bar of Hurst Castle joins the land, about half a mile south of the village of Milford, the shore rises into a low cliff, which, for a quarter of a mile, consists only of gravel; but at this spot the original strata appear, dipping a few degrees to the east. The cliff increases in height until it attains an elevation of about two hundred feet, and continues nearly to Muddiford without interruption, except where it is cut through by two streams that flow into the sea. The part properly called Hordwell Cliff, extends from the spot where the original strata first appear at the eastward, just below Milford, to a place called Long-mead End, a distance of a mile and a half. From Long-mead End to a gap in the cliff, occasioned by a stream called Beacon Bunny, is about half a mile, and is called Beacon Cliff. Barton Cliff reaches about two miles and a quarter from Beacon Bunny to Chuton Bunny, where another stream, rather more considerable, comes down. The remaining portion, which extends to within a quarter of a mile of Muddiford, is called High Cliff.

All these cliffs are capped by a bed of gravel, which, in Hordwell and Barton Cliffs, attains a thickness of at least fifty feet.

It is in Hordwell Cliff that the fresh-water formation is to be seen; the whole of the lower part of this cliff, indeed, consists of it, and not of the London clay;—which last is found only in Barton and High Cliffs; and it is in these cliffs that the shells, usually called Hordwell fossils, are found. The fresh-water shells, to be seen in the collections of these fossils, have not been found mixed with those of the London clay, but in a bed entirely distinct.

The fresh-water formation in Hordwell Cliff consists of various alternations of clays and marls. Some of the beds of clay are of a beautiful blueish-green colour, and others are blackish. Thin beds also occur consisting of hard calcareous marl, which appears to be derived entirely from shells of the fresh-water genera Limneus and Planorbis, of which numerous perfect specimens are to be found in it. A species of Paludina (Helix lenta of Brander) is also very common in this formation, occurring usually in layers; together with a great number of a beautiful small Melania and two species of bivalves.

In some parts of this bed I discovered also a prodigious number of minute fossil bodies, which, upon examination, are found to resemble the capsules of some vegetable. They are about the twentieth of an inch in diameter, of a flattened ovoid form, with the surface corrugated, and having a portion of the process by which they were attached still remaining: they are all hollow, and are in general divided, appearing as if they had burst open. They consist in their present state of lignite penetrated by pyritous matter. Fig. 3, Plate XII. represents one of these bodies of the natural size: and at fig. 4 are magnified views of it.

Towards the lower part of these fresh-water beds, there are numerous fragments of lignite, and beds a few inches thick of a substance resembling what the French call *tourbe pyriteux*.

Immediately below this formation at Hordwell, is found a bed of sand from sixty to one hundred feet thick: which appears first about Long-mead End, and may be well observed in the section at Beacon Bunny. This remarkable bed of sand forms one-half of the height of Barton Cliff, and is seen in the upper part of High Cliff, where it thins off and terminates beneath the gravel.

The bed which is identical with the London clay lies immediately below this sand: it commences on the east, at the level of the sea, between Longmead End and Beacon Bunny, and extends through Barton and High Cliffs: but it is in the upper part only that the fossils are numerous. This part of the bed may be twenty or thirty feet thick, and consists of a very sandy clay of a dark-green colour. Beneath it are some layers of large septaria; and there the clay is much less sandy, and contains fewer fossils. It is about Beacon Bunny that the fossils are found most conveniently; the upper part of the bed being easily accessible in that place: as the stratum increases in height, particularly at High Cliff, it is more difficult to reach the green bed. About Chuton Bunny are many large water-worn stony masses, with shells derived from beds in the London clay: and about the middle of the length of this cliff a stratum of sand appears below the clay, from which it is separated by a thin layer of rounded pebbles. This sand is of a dirty white, and contains many fragments of lignite, among which parts of branches, and a few even of the leaves of plants, may be distinguished. From its situation I consider this as the sand of the plastic clay: the fragments of vegetables, also, being very like those which accompany the lignite of that formation at Alum Bay. This bed is suddenly cut off by denudation before it reaches Muddiford, and then gravel forms the low cliff, which extends nearly to that place.

From a variety of reasons, I am induced to consider the fresh-water bed at Hordwell as corresponding to the *lower fresh-water* formation of the Isle of Wight. I have lately found this at East Cowes, at low water, with the same characters as at Hordwell: the beautiful green clay with Limnei and Planorbes being similar at both places. In my former paper, I mentioned that I had perceived, in connexion with the lower fresh-water formation, some alternations of beds containing marine and fresh-water shells, and in some places even mixtures of these. These mixtures are to be seen at Cowes; and at Hordwell I met with one specimen of a Cerithium: but the examination of this cliff, which is of great height and of difficult access, will no doubt afford traces of the passage to the upper marine formation. The imperfect lignite of Hordwell resembles that of Headen; and the Melania of Hordwell is to be met with in abundance in Thorness Bay, Isle of Wight. But it would be tedious to enumerate all the circumstances of resemblance that strike the observer, and which on the spot produce a conviction of the identity of this bed at the two places, very difficult to convey to others. The strongest argument, however, is derived from the subjacent strata: since in the Isle of Wight, a bed of white sand rests upon the London clay; and over this sand is the lower fresh-water formation; with the intervention, in some places, of a bed in which a mixture of marine and fresh-water shells is to be found.

The agreement of this series with that just described at Barton and Hordwell Cliffs furnishes a strong confirmation of the opinion I formerly advanced, with respect to the extent of what I have called the Isle of Wight Basin. And from the great thickness of this fresh-water formation in HordwellCliff, it cannot be doubted that it extends to a considerable distance inland; but how far I have yet had no opportunity of determining*.

* Since the preceding paper was read, Charles Lyell jun. Esq. has been so obliging as to transmit to me a specimen of shell marl, obtained from pits at a hill called Acres Down, and which is used for manure in the neighbourhood of Lyndhurst; from which it is evident, that the upper marine formation may be traced thus far: this marl consisting entirely of fragments of the same shells as are found in such numbers in that formation in the Isle of Wight.

VIII.—*On the Excavation of Valleys by diluvian Action, as illustrated by a succession of Valleys which intersect the South Coast of Dorset and Devon.*

By the Rev. WILLIAM BUCKLAND, F.R.S. F.L.S. V.P.G.S.
AND PROFESSOR OF GEOLOGY AND MINERALOGY IN THE UNIVERSITY OF OXFORD.

[Read April 19, 1822.]

MY intention in the following communication is to consider the general causes to which valleys owe their origin, and particularly such as occur in horizontal and undisturbed strata within the limits of their escarpments. That portion of the coast of Dorset and Devon which lies on the east of Lyme and on the east of Sidmouth, affords some of the best examples of such valleys with which I am acquainted: I beg therefore to present to the Society two geological views of that coast, drawn at my request some years since by Hubert Cornish, Esq., which will tend also further to illustrate the description given of it in a preceding paper by Mr. De la Beche.

Many valleys may be ascribed to the elevation or depression of the strata composing the adjacent hills, by forces acting at very remote periods from within the body of the earth itself; and to similar forces we may principally refer the high inclination and contortions of strata that occur in the highest mountains, and sometimes also in minor hills: other valleys have been occasioned by the strata having been originally deposited at irregular levels, and others by some partial slip or dislocation of portions of the strata.

But at different periods of time intermediate between the deposition of the most ancient and the most recent formations, the irregularities of level arising from the preceding causes have been variously modified by the action of violent inundations hollowing out portions of the surface and removing the fragments to a distance: to such circumstances we must ascribe the water-worn pebbles of the old red sandstone, the red marl, and the plastic clay formations.

A cause similar to that last mentioned has wrought extensive changes on the surface (however variously modified by preceding catastrophes) at a period subsequent to the deposition and consolidation of the most recent of the regular strata; for rocks and strata of all ages bear on those portions of their surface which are not covered by other strata, the marks of aqueous excavation; and are strewed over with the mingled fragments of the most recent, as well as of the most ancient beds.

The diluvian waters to which these effects must be referred, (if we except the very limited and partial action of modern causes, such as of torrents in cutting ravines, of rivers in forming deltas, of the sea in eroding its cliffs, and of volcanos in ejecting and accumulating their exuviæ,) appear to have been the last agents that have operated in any extensive degree to change the form of the earth's surface.

When one or more sides of a valley are formed by abrupt escarpments, such as usually terminate the outgoings of our secondary strata, it is difficult to say to what extent the discontinuity of the strata, and the formation of the valley beyond the limits of the escarpment, are attributable to diluvian excavation; for we know not how far the strata originally extended beyond their present frontier, nor how much of the subjacent valley is referable to other causes than the most recent diluvial agency: for example, it is not possible to determine how far the escarpment, which may be seen in the annexed map to terminate the green sand-hills of Blackdown towards the vale of Taunton, might have extended northward beyond its present boundary towards the Quantock hills; nor how much of this vale is to be attributed to excavation by water, or to originally low position: and we are equally without data for judging to what distance the same green sand might have originally extended on the west of Haldon towards Dartmoor; or over any spaces exterior to its present escarpments.

But when a valley originates and has almost its whole extent within the escarpment of strata that are horizontal or nearly so, and which bear no mark of having been moved from their original position by elevation, depression, or disturbance of any kind; and when such valley is inclosed along its whole course by hills that afford an exact correspondence of opposite parts, it must be referred exclusively to the removal of the substance that once filled it; and the cause of that removal appears to have been a violent and transient inundation *.

* For a well-digested statement of the arguments in support of the theory of the formation of valleys by aqueous excavations, I beg to refer to the works of Dr. Richardson on the coast of Antrim, in the Philosophical Transactions; to Mr. Greenough's Geology; and Mr. Catcott's Treatise on the Deluge: Mr. Catcott, however, has carried his doctrine of denudation too far, and has applied it to explain phenomena that must be referred to other causes.

It is not easy to imagine how valleys of this last description could have been formed in any conceivable duration of years by the rivers that now flow through them, since all the component streams, and consequently the rivers themselves which are made up of their aggregate, owe their existence to the prior existence of the valleys through which they flow.

Of the same nature with those last described are the valleys which intersect the coast of Dorset and Devon. In passing along this coast (see the Map and Views, Plates XIII. and XIV.) we cross, nearly at right angles, a continual succession of hills and valleys, the southern extremities of which are abruptly terminated by the sea, the valleys gradually sloping into it, and the hills being abruptly truncated, and often overhanging the beach or undercliff, with a perpendicular precipice. The main direction of the greater number of these valleys is from north to south; that is, nearly in the direction of the dip of the strata in which they are excavated: the streams and rivers that flow through them are short and inconsiderable, and incompetent, even when flooded, to move any thing more weighty than mud and sand.

The greater number of these valleys, and of the hills that bound them, are within the limits of the north and north-west escarpment of the green sand formation; and in their continuation southward they cut down into the oolite, lias, or red marl, according as this or that formation constitutes the substratum over which the green sand originally extended. There is usually an exact correspondence in the structure of the hills inclosing each valley; so that, whatever stratum is found on one side, the same is discoverable on the other side upon the prolongation of its plane: whenever there is a want of correspondence in the strata on the opposite sides of a valley, it is referable to a change in the substrata upon which the excavating waters had to exert their force.

The section of the hills in this district usually presents an insulated cap of chalk, or a bed of angular and unrolled chalk-flints, reposing on a broader bed of green sand; and this again rests on a still broader base of oolite, lias, or red marl (see Plates XIII. and XIV.). With the exception of the very local depression of the chalk and subjacent green sand and red marl on the west of the Axe, at Beer Cliffs, the position of the strata is regular and very slightly inclined; nor have any subterraneous disturbances operated to an important degree to affect the form of the valleys.

If we examine the valleys that fall into the bay of Charmouth from Burton on the east to Exmouth on the west, viz. that of the Bredy, the Brit, the Char, the Axe, the Sid, and the Otter, we shall find them all to be valleys of diluvian excavation; their flanks are similarly constructed of parallel and respectively identical beds; and the commencements of them all originate within the area and on the south side of the escarpment of the green sand.

The valley of the Sid, as it is coloured in the annexed map, may from its shortness and simplicity be taken as an example of the rest; it originates in the green sand, but soon cuts down to the red marl, and continues upon it to the sea; in both these respects it agrees with the upper branches of the Otter, and with the valleys that fall from the west into that of the Axe.

But in those cases where the lias and oolite formations are interposed between the red marl and green sand, the base of the valley varies with the variation of the substratum; as will appear on comparing the opposite sides of the lower valleys of the Otter, the Axe, and the Char, with the variations of their substrata, as expressed in the map.

The valley of Lyme is of equal simplicity with that of Sidmouth, and differs only in that its lower strata are composed of lias instead of red marl: but the valleys of Chideock, Bridport, and Burton, being within the area of the oolite formation, have their lower slopes composed of oolite subjacent to the green sand; whilst that of Charmouth is of a mixed nature, having its western branches in green sand reposing on lias, and in some of its eastern ramifications intersecting also the oolite. In the same manner, the valley of the Axe has lias interposed between the green sand and red marl on its east flank, but none at all on its western side, below the town of Axminster. These apparent anomalies form no exception to the general principle, that the variation of the sides of the valleys is always consistent with that which is simply referable to the variation of the substrata, on which the denuding waters had to exert their force. It is moreover such as can be explained on no other theory than that of the strata having at one time been connected continuously across the now void spaces which constitute the valleys.

The following section, taken from a series of lias quarries on the two opposite sides of the valley of the Axe near Axminster, will show the degree of minuteness to which this correspondence extends:

			Ft.	In.
1.	White lias...	Slaty and fissile, is used for flooring when split into slabs from two to three inches thick..	2	0
	Clay.			
2.	Burrs.	Rough blue building stone	0	10
	Clay.			
3.	Cockles.....	Flat and broad blue stone, containing shells and divided into two beds, each three inches thick, with a parting of clay; is used for building.—Total	0	10

		Ft	In.
Clay.			
4. Anvils......	Blue building stone, forming a bed of irregular anvil-shaped blocks	1	0
Clay.			
5. Graze Burrs.	Good blue building stone	0	10
Clay.			
6. Fire stone...	White building stone, used also for forming the arch-work of lime pits: it divides into two beds, each four inches thick, with a parting of clay.—Total	1	0
Clay.			
7. Half-foot bed.	Strong blue flagstone, the best for paving .	0	6
Clay.			
8. Foot stone...	Blue paving and building stone	0	10
Clay.			
9. Red-size....	White lias, inclining to grey, splitting into two or three thin slabs, and used for paving and building	0	6
Clay.			
10. Under bed. .	Blue building stone, used for paving, and the best bed of all for steps	0	8
Clay, varying from one to six feet.			
11. White rock.	White lias, rough and rubbly throughout;—not good for paving or building, but used largely to make lime, which is better than that of the other beds for plastering and in-door work: the thickness of this bed is variable; its average is	30	0

All the above strata are separated by thin beds of clay, varying from four inches to a foot, and exceeding the latter thickness in one case only, viz. between N^os 10 and 11: but the presence and relative position of each individual stratum of stone is constant; and the specific character and uses of each bed are of practical notoriety among the masons through the district round Axminster, in which there are many and distant quarries, to any one of which the above section is equally applicable; *e. g.* to the quarries of Fox hills on the south-east, of Waycroft on the north, and of Sisterwood, Battleford, Long Leigh, Small-ridge, Green-down, and Cox-wood, on the north-west of Axminster. There can be little doubt, therefore, that the component strata of all these quarries were originally connected in one continuous plane across the now void space which forms the valley of the Axe*.

The fact of excavation is evident from simple inspection of the manner in which the valleys intersect the coast, on the east of Sidmouth and the east of Lyme, as represented in the annexed views (Plate XIV.); and it requires but little effort, either of the eye or the imagination, to restore and fill up the lost portions of the strata, that form the flanks of the valleys of Salcomb, Dunscomb, and Branscomb, on the east of Sidmouth; or of Charmouth, Seatown, and Bridport, on the east of Lyme. By prolonging the corresponding extremities of the strata on the opposite flanks, we should entirely fill up the valleys, and only restore them to the state of continuity in which they were originally deposited.

An examination of the present extent and state of the remaining portions of the chalk formation within the district we are considering, will show to what degree the diluvian waters have probably interrupted its original continuity. The insulated mass of chalk, which at Beer Head composes the entire thickness of the cliff, rises gradually westward with a continual diminution and removal of its upper surface; till after becoming successively more and more thin, on the cliffs of Branscomb, Littlecomb, and Dunscomb, it finds in the latter its present extreme western boundary: beyond this boundary, on the top of Salcomb Hill and of all the highest table lands and insulated summits of the interior, from the ridges that encircle the vales of Sidmouth and Honiton to the highest summits of Blackdown, and even of the distant and insulated ridge of Haldon on the west of the valley of Exe, beds of angular and unrolled chalk flints (which can be identified by the numerous and characteristic organic remains which they contain) are of frequent occurrence; similar beds are found also on the green sand summits that encircle the valleys of Charmouth and Axminster; other large and insulated masses of chalk occur, along the coast from Lyme nearly to Axmouth, and in the interior, at Widworthy, Membury, White Stanton, and Chard; and these at distances varying from ten to thirty miles from the present termination of the chalk formation in Dorsetshire; though within the limits of the original escarpment of the green sand.

These facts concur to show that there was a time when the chalk covered all those spaces on which the angular chalk flints are at this time found: and

* The section of these quarries is also important as proving the alternation of white lias with blue: it is more common to find the white variety occupying only the lower regions of this formation; but in the case before us there is not only this alternation, but each individual slab of blue lias is inclosed within an outer crust or case of white lias; the colour of which passes by insensible gradations into blue.

that it probably formed a continuous or nearly continuous stratum, from its present termination in Dorsetshire, to Haldon on the west of Exeter *.

From the correspondence observed by Mr. Wm. Phillips between the strata of Dover and on the hills west of Calais †, and by Mr. De la Beche between the strata of the coast of Dorset and Devon, and those of Normandy ‡, it may be inferred (after making due allowance for the possible influence of those earlier causes, which in many instances have occasioned valleys) that the English Channel is a submarine valley, which owes its origin in a great measure to diluvian excavation, the opposite sides having as much correspondence as those of any valleys on the land. Mr. De la Beche, as I am informed, has already drawn the same inference from his own observations. According to Bouache, the depth of the straits of Dover is on an average less than 180 feet; and from thence westward to the chops of the channel the water gradually deepens to only 420 feet, a depth less than that of the majority of inland valleys which terminate in the bay of Charmouth; and as ordinary valleys usually increase in depth from the sides towards their centre, so also the submarine valley of the channel is deepest in the middle, and becomes more shallow towards either shore.

It seems probable that a large portion of the matter dislodged from the valleys of which we have been speaking by the diluvian waters that hollowed them out, has been drifted into the principal valley, the bed of the sea; and being subsequently carried eastward by the superior force of the flowing above that of the ebbing tide, and partially stopped in its further progress by the Isle of Portland, has formed that vast bed of pebbles known by the name of the Chesil Bank: the principal ingredients of this bank are rolled chalk flints and pebbles of chert; the softer materials that filled the valleys, such as chalk, sand, clay, and marl, having been floated off and drifted far into the ocean, by the violence of the diluvian waters.

* There is also reason to think that the plastic clay formation was nearly coextensive with the chalk; for on the central summits of Blackdown there are rounded pebbles of chalk flint, which resemble those found in the gravel beds of the plastic clay formation at Blackheath: and on the hills that encircle Sidmouth there are large blocks of a siliceous breccia, composed of chalk flints united by a strong siliceous cement, and differing from the Hertfordshire pudding-stone only in the circumstance of the imbedded flints being mostly angular, instead of rounded as in the stone of Hertfordshire: a variation which occurs in similar blocks of the same formation at Portisham, near Abbotsbury, and elsewhere.—The argument, however, arising from the presence of these blocks and pebbles is imperfect; as it is possible, though not probable, they may have been drifted to their actual place by the diluvian waters, *before* the excavation of the valleys.

† See Geological Transactions, Vol. v. pp. 47, &c.

‡ See p. 89 of the present volume.

The quantity of diluvian gravel which remains lodged upon the slopes and in the lower regions of the valleys that intersect this coast, is very considerable; but it is not probable that many animal remains will be discovered in it, because the large proportion of clay with which it usually is mixed, renders it less fit for roads than the shattered chert strata of the adjacent hills, and consequently gravel pits are seldom worked in the diluvium. Enough, however, has been done to identify its animal remains with those of the diluvian gravel of other parts of England, by the discovery, a few years since, of several large tusks of Elephants and teeth of Rhinoceros in the valleys of Lyme and Charmouth.

On the highest parts of Blackdown, and on the insulated summits which surround the vale of Charmouth, I have found abundantly pebbles of fat quartz; which must have been drifted thither from some distant primitive or transition country, and carried to their actual place, before the present valleys were excavated and the steep escarpments formed, by which those high table lands are now on every side bounded. These cases are precisely of the same nature with those of the blocks of granite that lie on the mountains of the Jura and on the plains of the north of Germany and Russia, and with that of the quartzose pebbles found on the tops of the hills round Oxford and Henley; which latter I have described in the fifth volume of the Geological Transactions, as having been drifted thither from the Licky Hill and central parts of England, before the excavation of the present valley of the Thames.

IX.—*Additional Notices on the Fossil Genera Ichthyosaurus and Plesiosaurus.*

By the Rev. WILLIAM D. CONYBEARE, M.G.S. &c.

[Read May 3, 1822.]

IN the former communication which I had the honour of submitting to the Society, on the subject of the fossil remains of animals belonging to the Saurian order, it was my object to give a general outline of the facts which my own observation, or that of others, had enabled me, up to that period, to ascertain concerning the genus Ichthyosaurus; and to introduce to the knowledge of the public a new genus, which my own inquiries, assisted by those of Mr. De la Beche, had enabled me to constitute, and to which I appropriated the name of Plesiosaurus.

It is my present intention to redeem the pledge I gave of endeavouring to fill up the outlines which I then offered, so far as the additional facts gathered in the researches of another year, the examination of many new and illustrative specimens, and my correspondence with scientific friends, have enabled me to do so. Were I at liberty to acknowledge all my obligations to those friends, I should at once disclaim for myself a large share of any merit that may be supposed to be attached to the prosecution of these inquiries, and at the same time confirm the results I have to state by authority far superior to my own. And I wish it to be understood, that I have again received, throughout, the assistance of Mr. De la Beche, and continued to derive material information from the fresh specimens which have found their way into the collection of Colonel Birch.

ICHTHYOSAURUS.

The new materials which have been collected respecting this genus will enable me to lay before the Society an examination of many points concerning its structure, which before could be only generally stated; a description of some parts of the skeleton previously unascertained, particularly those connected with the back of the mouth and head; an attempt to discriminate the species of this genus; and a fuller statement of the analogies which must determine its place among the different classes of lacertæ. I had originally, it will be remembered, compared it principally to the crocodile; and after a very mature examination, I am still of opinion that the analogies between the Ichthyosaurus and that family are more striking and numerous, than those which connect it with the other tribes of Lacertæ. But to judge of the relative value of conflicting analogies is one of the most delicate and difficult points of comparative anatomy; and I shall throughout confine myself to stating simply those analogies, whatever may be their tendency, leaving those who may be more competent to such a task, to decide on the conclusions to be deduced from the whole evidence*.

I need not repeat, what is fully agreed on all hands, that the Ichthyosaurus is an animal entirely *sui generis*; possessing, however, sufficient analogies with the Saurian order to justify our referring it to that great natural division. It is likewise agreed, that in respect of certain analogies, it is allied most nearly to the crocodilian branch, and in respect of others to the lacertian branch of that order: and the remaining question, to which of these it approximates most nearly, is one, after all, of very subordinate importance. Concerning this most material point, viz. that the animal was exclusively an inhabitant of the sea, no doubt has been expressed by any of those who have most attentively considered its structure.

It is very satisfactory to me to be able to state, that the progress of my inquiries, though it has afforded clearer views on many points, has scarcely in any material circumstance obliged me to alter those which I have had the honour of laying before the Society on a former occasion. Some slight modifications will be found in the course of the following observations; but there are only two points which appear to require a more prominent notice;—

* It cannot be too often pressed on the zoological observer, that he must carefully keep in view the collective tendency of all the analogies presented by the subject before him: in no department of inquiry are we more liable to fall into error from hasty induction. To instance this in a recent animal, the Ophisaurus: were the head alone of this animal known, no person acquainted with comparative anatomy would hesitate to pronounce that it belonged to a Lacerta, and was connected with a body having regular quadrupedal extremities; yet in truth its body belongs to an entirely different system, being that of a regular Serpent. In the same manner in the fossil genus Ichthyosaurus, the head of a lacertian animal is joined to the vertebræ of a fish and extremities entirely *sui generis*. Beautiful as is the doctrine of the laws of coexistence in the parts of animals, so admirably illustrated by Mr. Cuvier, it yet requires to be applied with all the caution so conspicuous in the writings of this naturalist, to render it a secure instrument of investigation.

First; in comparing the large holes behind the orbit in the ichthyosaurus with those in the crocodile, I ought to have noticed that they have a still closer analogy with the temporal fossæ in the other lacertæ. The use of the cavities in question in the skull of the crocodile not having been, at that time, clearly explained, and these cavities having been erroneously described as peculiar to that animal, an obscurity was thrown over the whole of this part of the subject. Subsequent information and my own further examination have satisfied me, that they are the true temporal fossæ of the crocodile, and do not differ, except in their smaller size, from those of the remaining lacertæ. The ichthyosaurus, in respect to this part, appears to hold an intermediate place between the crocodile and the lacertæ; but certainly approximates most nearly to the latter: so that thus far I must correct my former statements.

The second point to which I am desirous of adverting, in limine, is the representation given of the roof of the mouth, in fig. 12. Pl. 40. Vol. V. I have reason to believe, from the examination of nearly perfect specimens since discovered (see Pl. XVII. of the present volume), that the fractured state of the specimen from which the drawing for the former plate was taken, and also the irregular line of section it presented, have occasioned an exhibition of these parts in some respects incorrect.

The figures of the head of the ichthyosaurus, given in the former communication, were, in many instances, restorations made up from the comparison of many different specimens. Indeed, had not this method been adopted, it would have been impossible to communicate, without a large apparatus of engravings, the general information which alone it was my object, at that time, to impart. In my present communication I shall submit drawings from individual specimens only; a method far more satisfactory, where it is practicable within reasonable limits: and it will be seen that these figures fully confirm the restorations attempted in the preceding memoir.

In proceeding to the details which I now propose to offer, I shall consider,

I. The Dentition of the Ichthyosaurus.—In my former paper on this subject, following the authority of Sir Everard Home, I simply stated a general agreement with the dentition of the crocodile: but from the importance attached to this branch of the subject by most anatomical writers, I have since been induced to examine the matter more minutely; especially as I have found a disposition in some scientific friends, to whom my observations were communicated, to compare the dentition of the ichthyosaurus rather with that of the other lacertæ. It will be necessary, in the first instance, to state in what points the dentition of the crocodile differs from that of the other members of the great Saurian family.

In the crocodile, the teeth are lodged loosely in distinct alveoli: they always remain hollow: the new tooth first appears as a germ on the inner face of the root of the old tooth, where, preventing the growth, it occasions a fissure; through which, as it continues to elongate itself, it penetrates into the hollow of the old tooth: and, lastly, by its increase it splits the old tooth, the fragments of which it causes to fall off. There being in the crocodile a continual succession of fresh teeth, and not a single change as in man (and as in most, I believe, of the mammalia), the teeth are never filled up by the ossification of their pulpy interior, but always continue hollow:—and the process above described may be traced as going on in the jaws of crocodiles of all ages.

In the other lacertæ, on the other hand, the teeth are not lodged in alveoli, nor even in a continuous furrow; but the jaw bone presents only (if the expression may be allowed) a sort of parapet on the outer side; and the teeth are fixed to it by a bony mass occupying the place of their root, and incorporated organically both with the tooth and with the jaw bone. The new teeth make their first appearance, in cells, from within this osseous mass, and shoot irregularly through its substance, gradually producing a necrosis in it, and thus causing both the mass and the old tooth which it supports, to fall.

Finally, the tooth in these genera becomes completely solid, its interior cavity being filled up by the ossification of the pulpy substance; so that they do not appear to have many recurrences of fresh sets of teeth, and perhaps have only one.

The first two figures of Plate XV. represent the dentition of the crocodile; the third, that of the fossil animal of Maestricht, which entirely agrees with the ordinary lacertian type. Let us proceed to institute a comparison between the teeth of these, and of the ichthyosaurus.

1st, The teeth of the ichthyosaurus are lodged loosely in a long continuous furrow, retained only, as it would appear, by the substance of the gum. This structure is widely different from that of the monitors and ordinary lacertæ, where the teeth adhere to the jaw by a solid bony union. It differs much less from that of the crocodile; the only variation being, that the alveoli (which in the crocodile are separate) here run together into one long continuous furrow;—in which indeed the rudiments of a separation into distinct alveoli may be traced, in the slight ridges extending, between the teeth, along the sides and bottom of the furrow. (See Pl. XV. fig. 12.) As corroborating this analogy, I am informed that, in the crocodile, the three or four posterior alveoli often run together into a continuous furrow, exactly in the same manner.

2dly, The appearance and progress of the new tooth, which is to replace the old one, is very nearly the same in the ichthyosaurus and in the crocodile. This will be best seen by comparing figs. 4, 5, and 6, Pl. XV. which represent the dentition of the former, with figs. 1 and 2, which represent that of the latter. In fig. 4. is seen a tooth of an ichthyosaurus, in which a fissure has been effected in the side of the root, by the growth of the new tooth. In fig. 2, a crocodile's tooth under the same circumstances, an exact agreement will be observed in this respect. Fig. 5. represents a section passing longitudinally along the jaw, and exhibiting the new tooth, which has penetrated the interior cavity of the old one. Fig. 5, *b*, shows the appearance of the upper surface of this specimen, where the tops of the old and new tooth are broken off. Fig. 6. represents a similar section passing transversely across the jaw-bone. In this figure the jaw-bone itself and the canal which traverses it for the passage of the nerves and vessels are exhibited. These two figures may be compared with fig. 1, which represents the appearance of the new tooth of the crocodile, when it has penetrated the interior cavity of the old one. The agreement will be found exact. But if a comparison be instituted with fig. 3, (representing the dentition of the fossil animal of Maestricht, and of the lacertæ distinguished by generic characters from the crocodile,) a great difference will be seen: for in these last two cases the new tooth, instead of shooting into the interior of the old one, shoots irregularly across the osseous mass, incorporating it with the jaw-bone.

It should be observed, that in all these instances the new tooth, when it first makes its appearance, consists only of a hollow conical shell of enamel, which increases in length by the apposition of osseous matter at the lower edge, gradually forming its root.

3dly, In pursuing, however, the history of the teeth of the ichthyosaurus to the last stage, we quit these analogies with the crocodile, and arrive at another point, wherein the ichthyosaurus resembles the other lacertæ, in common with many of the mammalia. This is the gradual obliteration of the interior cavity in old age, by the ossification of the pulpy nucleus. Fig. 13. Pl. XV. represents a transverse section of the root of a tooth, in which this process has taken place. The ossified pulp has become a spongy mass of reticulated bony fibres; and the osseous laminæ forming the exterior of the root, are seen surrounding it in wavy cortical layers; not, however, continuing all round the tooth, but interrupted by openings corresponding to the furrows that mark the outside of the tooth; between which openings the spongy substance insinuates itself. The only inference from this filling up of the interior cavity in the teeth of the ichthyosaurus is, that in this animal the succession of new sets of teeth was but seldom repeated, and perhaps not more than once.

II. Determination of the different Species of Ichthyosaurus from their Teeth.—When we consider the different forms which the same bones are known to receive in the same animals at different ages, it is not possible to approach without hesitation so delicate a problem, as that of determining, from the teeth alone, the species of an animal, our knowledge of which depends entirely upon fossil remains, often mutilated and obscure. Mr. De la Beche, however, long since believed himself able, from the examination of the teeth, combined with some other characters, to establish three species, to which he has applied the names *communis, platyodon,* and *tenuirostris:* and to these our joint observations have recently added a fourth, Ichthyosaurus *intermedius.* All these occur in the formation of lias. The ichthyosaurus whose remains are found in the Kimmeridge clay, appears to belong to yet another species: but our knowledge of its structure is not yet sufficiently precise, to enable us to describe it. We have not seen its teeth; and its distinctive characters depend, at present, on its cervical vertebræ.

The distinctions of teeth in the first four species above enumerated are as follows: (see Pl. XV.)

1. I. communis. (fig. 8.) Upper part of the tooth conical, not very acute, slightly aduncate, and thickly covered with prominent longitudinal striæ.

2. I. platyodon. (fig. 7.) Upper part of the tooth smooth and flattened, so as to present sharpened edges. (See transverse section at c. fig. 7.)

3. I. tenuirostris. (fig. 10.) In this the teeth are much more slender than in the preceding species. But the species is best marked by the extreme length and thinness of the snout, in which points it very strikingly exceeds all the other ichthyosauri.

4. I. intermedius. (fig. 9.) The upper part of the teeth is much more acutely conical than in I. communis, and the striæ less prominent: yet they are less slender than in I. tenuirostris. This species is also distinguished by differences (presently to be noticed) in the angular and coronoid bones of the lower jaw.

The specimens of I. platyodon are generally large: the most gigantic yet discovered are referable to this species. The specimens of I. communis occur of very different sizes; such as may have belonged to animals from five to fifteen feet in length when entire. Those of I. tenuirostris and I. intermedius appear not to exceed one half the largest size of I. communis:—these last observations, however, are offered with much diffidence, as it must be obviously impossible to obtain from the examination of a few individuals a certain determination of the size of the species when full grown.

III. Structure of the lower Jaw.—In order to indicate more clearly the analogies of the ichthyosaurus in this part of its structure, I shall compare each of the bones of its lower jaw with the corresponding bones both of the crocodile and of the other lacertæ.

1. *The Dental bone.*—The furrow which contains the teeth, exhibiting in the slight ridges that traverse it the rudiments of a division into distinct alveoli, approximates (as has been seen) much more nearly to the analogous part in the crocodile, than to that in the other lacertæ. See fig. 12. Pl. XV.

Another circumstance, however, has an opposite bearing: namely, the distribution of the holes on the outside of its anterior portion, which convey the branches of the inferior maxillary nerve and vessels. These in the crocodile exhibit a series of small dots irregularly dispersed; in the other lacertæ and in the ichthyosaurus they appear as a regular row of conspicuous perforations. See fig. 12. Pl. XV. and fig. 6. Pl. XVI.

The ichthyosaurus has eight or nine of these perforations, branching out laterally from the canal which runs longitudinally through the substance of the dental bone. The posterior branches are inflected backwards, the anterior forwards. As these branches are sent out from the central canal to the exterior, so there are others directed to the interior, to supply the teeth. Fig. 12. Pl. XV. exhibits a portion of the dental bone, partly cut away, in order to expose this central canal and its branches. The same thing is also shown in Pl. XVI. fig. 6.—and in the section, fig. 1.

2. *The Angular bone.* 3. *The Coronoid bone.* and 4. *The Crescent-shaped bone.*—The structure of all these bones is essentially connected with the disposition of the muscles moving the lower jaw; namely, the temporal, the masseter, and the pterygoid muscles. The crocodile in these respects exhibits a peculiar conformation; of which a large oval hole, placed at the junction of the dental angular and coronoid bones, affords a strong osteological indication. The organization to which it belongs is as follows:—In many species of crocodile the temporal muscle (the grand motor of the lower jaw in most animals) is scarcely more than a rudiment: and although in the gavial, where the great length of the lever to be acted upon requires an increase of power, this muscle is more developed; still, even here it is but imperfectly displayed. In order to compensate for this deficiency, the masseter, on which the additional functions usually belonging to the temporal muscle thus devolve, re-

ceives a much greater developement*.—Hence also the coronoid process, the use of which is to receive the main action of the temporal muscle, can hardly be said to exist at all in the crocodile ; while on the other hand, an oval hole is formed in those parts of the lower jaw that give attachment to the masseter, in order to afford a more powerful adhesion. For this purpose, across the oval hole is stretched a strong fibrous membrane, into which, on the outside, are inserted the fibres of the masseter;—and on the inside those of the pterygoid, and internal portions of the imperfectly-formed temporal muscle †.

In the other lacertæ,—where the temporal muscle is the great motor of the lower jaw, and the masseter has only its ordinary functions,—the coronoid process is of considerable extent, being formed by a long process of the crescent-shaped bone ; and there is no large oval hole, but only a sinus in its place, for the insertion of the masseter.

Now the ichthyosaurus appears to possess an intermediate structure in these respects : for although the oval hole, which characterizes the crocodile, is wanting (being represented only by a sinus in the coronoid), yet the coronoid process itself appears to be far less developed than in the other lacertæ, although more so than in the crocodile. It appears also to be formed entirely by a process of the coronoid bone, not by the crescent-shaped bone ; although this latter exists on the inner side of the jaw. I am not, however, able to speak with certainty of the termination of the coronoid process, or of the exact outline of the crescent-shaped bone ; all the specimens which I have seen having been obscure in these parts. I would particularly refer to fig. 14. Pl. XVI. which represents the interior of the lower jaw in the specimen exhibited at large in fig. 8. of the same plate. The bones are here distinguished by the letters employed throughout these papers. *z* represents the crescent-shaped bone ; but its outline is much concealed by investing pyrites. Above *x* there appears

* I have to acknowledge my obligations to a friend, for many of these observations on the parts connected with the temporal and masseter muscles.

† These characters belong generally to all the recent species of crocodile ; but in the fossil species described by M. Cuvier, the oval hole was wanting (see his memoir on fossil crocodiles, p. 20.) ; and in all the fossil species of this genus which I have myself examined, the temporal fossæ were much more developed than even in the recent gavial. I am persuaded, from every circumstance, that a much nearer approximation to the structure of the other Lacertian genera will be found in the fossil, than in the recent crocodiles : interesting links in the chain of Saurian animals will be thus supplied ; and it will probably be found that many of the points in which the ichthyosaurus differs from the recent type, are only instances of its agreement with the fossil.

to have been a projecting process, broken off from the inner side of the coronoid bone: *y* is a portion of the articular bone of the lower jaw.

In the left lower jaw of the head figured in Pl. XVII. the interior is well displayed; and this projecting process from the inner side of the coronoid seems distinct. In this specimen, however, the crescent-shaped bone cannot be clearly made out, the jaw being slightly crushed and fractured in this part.

I wish to direct the further inquiries of those who may possess specimens, to these points. Dry and uninteresting as such details must necessarily be, they acquire importance from their connexion with so essential a point as the muscular action employed in moving the lower jaw.

Although in the points which have been mentioned, the angular and coronoid bones (or rather the latter) of the ichthyosaurus approximate more nearly to those of other lacertæ than of the crocodile; yet I have next to notice a configuration, very striking in the character it imparts to the posterior part of the jaw, which brings them back again to the latter type; namely, their extending, as in the crocodile, so far back, as to cover and conceal on the exterior the whole of the articular bone; whereas in the other lacertæ the articular bone, forming the posterior end of the lower jaw, is displayed for some distance on the outside as well as the inside.

5. *The Articular bone.*—This affords room for no remark, except in being concealed on the outside, both in the crocodile and ichthyosaurus, as just stated. It may be seen, marked *y*, in the sketch of the inner side of the jaw, fig. 14. Pl. XVI.; and in the left lower jaw of the head, Pl. XVII.

6. *The Opercular bone,*—affords no distinctive characters*, but very closely agrees with that of the crocodile.

On the whole, then, if the lower jaw in the ichthyosaurus is compared with that of the crocodile and other lacertæ, the analogies will stand as follows:—The extension of the angular and coronoid bones, so as to cover the articular, renders the posterior extremity exactly like that of the crocodile; and the furrow carrying the teeth, though strictly speaking *sui generis*, yet approximates most nearly to the alveolar dental of the crocodile. On the other hand, the perforations for the exterior distribution of the branches of the lower maxillary nerve, closely resemble those in the lacertæ; and the absence of the oval hole is a character of the same kind, though common perhaps to some of the fossil species of crocodile also. The structure of the coronoid process appears to hold an intermediate place.

* This bone is very little developed in some of the lacertæ; but in others it acquires almost as great an extent as in the crocodile.

Before quitting the lower jaw, I wish to call the attention of the reader to two series of transverse sections, exhibiting the arrangement of its bones, from very perfect specimens. See figures 1. to 5. and 9. to 13. Plate XVI.

A similar series was given in the former memoir, already referred to; but had the disadvantage of being made up from different specimens. The present, being deduced from two individuals only, illustrates this subject with more certainty; since a variation, arising from difference of species or of age, might be suspected in the former instance. The specimens now figured are also remarkably free from compression.

The first of these series (figs. 1. to 5.) is taken from the anterior portion of a very large lower jaw of ichthyosaurus platyodon, in the possession of Mr. De la Beche; of which a lateral view is given in fig. 6: and the bottom is represented, with its hinder extremities restored, from another specimen, in fig. 7. The second series (figs. 9. to 13.) includes only the posterior half of the lower jaw, and is taken from the very fine specimen of ichthyosaurus communis belonging to the Oxford collection, which is shown entire at fig. 8. Pl. XVI. The section, fig. 4. nearly corresponds, as to the place of the line in which it traverses the jaw, with that marked 13.; and fig. 5. with fig. 12.; so that the slight differences which exist, may be considered as characterizing the different species.

In comparing these with the figures given in the former memoir, Vol. V. Pl. 40. it will be observed,—that whereas in the specimens of I. communis and I. platyodon now figured, the coronoid bone disappears on the outside (being overlaid and concealed by the overhanging flap of the dental) before the similar concealment of the angular bone,—in those formerly figured the angular draws itself up beneath the coronoid, before the coronoid is thus covered up itself. The latter structure is apparently characteristic of the species I. intermedius, and will be seen well displayed in the lower jaws of the beautiful specimen figured in Pl. XVII.

Fig. 7. of the sections in the first memoir (Vol. V. Pl. 40.) appears to require correction, where the dental bone, *u*, is represented as ending in a thick knob. An accidental fissure must in this instance have been mistaken for the true suture between the bones, since in every other instance the dental expires in a thin plate.

I would particularly invite attention to the beautiful manner in which these bones appear to be packed and adjusted together in the series now figured.

Another striking contrivance in the structure of this composite lower jaw deserves to be noticed. Where the coronoid is interposed between the dental and opercular, its fibres have a slanting direction; while those of the two latter bones are horizontally disposed: thus the strength of the part is greatly increased by a regular diagonal bracing, without the least addition of weight or bulk. A similar structure may be noticed in the overlapping bones of the heads of fish, and in a less degree also in those of the turtle.

IV. Nostrils and Anterior Part of Upper Jaw.—Some general remarks may be added to what has been said in the former memoir on the structure of these parts.

Nature designed both the ichthyosaurus and the crocodile to possess elongated muzzles; but she has in the two instances varied the usual Saurian type, in order to produce this effect in a very different manner. In the crocodile she has given extraordinary length to the maxillary bones; and, removing the nostril from its usual place, transferred it to the extremity of the intermaxillary bones. The reason for this may probably be, that the crocodile lurks for prey near the banks of rivers, with the tip alone of his long snout out of the water. At that point, therefore, the nostril was necessarily placed, to enable him to scent his food. But to the ichthyosaurus, living in the sea, such a position of the organ would have been useless: as in the lizard, therefore, in the monitor, and indeed in most quadrupeds, this opening is placed between the nasal, maxillary, and intermaxillary bones; and the prolongation of the snout is principally effected by an unusual elongation of the intermaxillary bones.

The position of the nostril in the crocodile, moreover, gives unusual development to the nerves of the olfactory organ; the sense of smell must therefore be very acute in that animal. But in the ichthyosaurus, the parts connected with the organ being small in their proportions, the sense was probably dull. This has been insisted on as an important distinction between the two genera *.

V. Eye and Orbit.—These parts give rise to no new remarks. The bony plates of the sclerotica present a difference from the crocodile, and an agreement with the other lacertæ.

VI. The Temporal Fossæ.—In the head of the crocodile, two fossæ may

* It should be observed, that in the sketches of the head of ichthyosaurus accompanying the first memoir, the posterior end of the intermaxillary bones has been carried somewhat too far back, being made completely to encircle the opening of the nostril; whereas it should have been confined to the anterior margin of that opening, which is bounded by it; as is the lower margin by the lacrymal, and the superior by the nasal bone. The position of the nostril between these three bones answers to that in the lacertæ. This part is correctly represented in Pl. XVII. of the present volume.

be observed on either side the post-orbital part of the head * ; that is to say, an upper fossa, included between the parietal bone (*m*), the post-orbital part of the frontal (*h'*), and the part of the temporal (marked *n*), which from its analogies I should wish to designate as the squamoso-zygomatic bone ; and a lower fossa immediately beneath the first, included between the post-orbital process of the frontal (*h''*), and the post-orbital process of the jugal (*c*); the portion of the temporal which surrounds the cavity of the tympanum and carries the condyle of articulation with the lower jaw, answering to the os quadratum of birds (*o*) ; and another bone (marked *p*), interposed between the last and the jugal, and considered as another dismemberment of the temporal.

I am obliged to recur to these circumstances, because much confusion has existed with regard to these two fossæ ; the lower fossa having been considered as the true temporal fossa, and the upper as peculiar to the crocodile ; whereas in fact the reverse is rather the true representation of the case.

The upper fossæ are undoubtedly the true temporal fossæ. A comparison with the temporal fossæ of the other lacertæ will at once prove this, for both are included by the very same bones ; namely, the parietal, posterior frontal, and the squamoso-zygomatic portion of the temporal : the upper branches of the temporal muscle are also attached round the edges of this fossa.

There is much difference in the size of this upper fossa in different species of crocodile. In the Crocodilus sclerops it does not exist at all, the space in which it ought to occur being covered up by the extension of the contiguous bones ; in the gavial, on the contrary, it is considerably larger than in other species†. A friend, possessed of great anatomical knowledge, has pointed out the true cause of this difference. The gavial, having a much longer lever to move in its lower jaw than the other crocodiles, requires a stronger muscular action. The temporal muscle, therefore, which is little employed in the other species, and exists only as a rudiment, (its functions being supplied, as we have already seen, by the masseter,) is in the gavial more developed, and consequently the temporal fossæ require and receive a greater extension.

The lower fossæ appear also to be subsidiary to the main or upper temporal fossæ, and, perhaps, are also connected with the attachment of branches of the masseter ; but I have not seen a clear explanation of the attachment of the muscles in this part.

In the other lacertæ there are no lower fossæ ; but the contour of the part

* I have again to acknowledge my obligations to a friend for many important observations on these temporal fossæ.

† I speak here of recent species : some fossil species of crocodile have this fossa still larger than the recent gavial.

which these occupy is completely altered, and the lower portion of it is as it were broken through; those bones which form the inferior margin of these lower fossæ being wanting,—namely, the prolongation of the jugal (*c*) behind the orbit, and the bone (*p*) between this and the tympanal portion of the temporal, or os quadratum; and the tympanal bone itself being so placed as to hang as it were loosely among the other bones of the head, by its upper portion, instead of wedging itself in among them as in the crocodile.

The temporal fossæ in the lacertæ, on the other hand, answer entirely to the upper fossæ in the crocodile; with the exception already stated, namely, that, in order to give room to a much more powerful temporal muscle, they have a much greater proportional extent.

Having in my former memoir compared the head of the ichthyosaurus principally with that of the crocodile, I at once perceived that the post-orbital holes on the top of the skull of the former animal corresponded exactly, in position, and in the bones by which they are surrounded, with the upper fossæ in the crocodile: but as these appeared, in the accounts of the crocodile which I had read, to be considered as peculiar to that animal, I did not carry my researches further. Having since ascertained the true character of these fossæ, as being the principal temporal fossæ, and as answering to those of the other lacertæ, I must of course retract any inferences deduced from having considered this part as peculiarly approximate to the crocodilian type; for it will be found, in truth, that it presents a slight modification only of the usual position of the temporal fossæ, and indeed agrees more closely with the skulls of other lacertæ than with that of the crocodile; inasmuch as the fossæ are larger than in the crocodile, and the contour of the surrounding bones, especially the forked outline of the back of the parietal bone, is similar in character to the lacertian type; to which, therefore, rather than to the crocodile, the analogies derived from hence must, so far as they go, incline us to refer the present genus.—But when it is considered how much wider variations exist in this part between different species of crocodile (the sclerops for instance and the gavial), the differences between this last species and the ichthyosaurus will not, I think, appear of very considerable weight. In the remaining part of the head we find distinctions of much more obvious and striking importance, which give to its posterior portion a character strongly approximating to the crocodile, and very widely removed from the other lacertæ.

I have not been able to ascertain whether the lower fossæ* of the crocodile

* The fossa, however, connected with the external opening of the tympanal cavity (see the following paragraph and Plate XVI.), appears also to have an opening anteriorly (behind *p*); and this anterior opening may perhaps represent the fossa in question.

can be traced in the ichthyosaurus: they may perhaps be covered by the extension of the conterminous bones. But still the general outline is preserved; for this part is not broken into as in the lacertæ, but an intermediate bone (*p*) occurs, connecting the jugal (*c*) and the lower part of the os quadratum (*o*). The analogies of this part of the head with the crocodile will appear yet more strongly in the following statement.

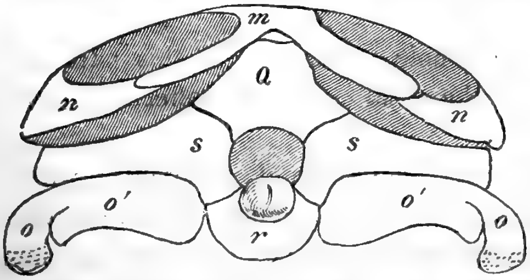
VII. Position of the Tympanal Bone, or Os Quadratum, and Parts surrounding the external Opening of the Tympanal Cavity.—The bone analogous to the os quadratum, or that part of the temporal which articulates with the lower jaw and in part surrounds the tympanal cavity, is placed quite loosely in all the lacertæ (as distinguished from the crocodile); being attached only by its upper extremity to the superior or squamoso-zygomatic branch of the temporal (*n*) at its junction with the mastoid. In the crocodile, on the contrary, it adheres firmly between this bone and all the others in its neighbourhood, being connected with the jugal by the interposed bone (*p*). In all these features the position of the os quadratum in the ichthyosaurus agrees entirely with that in the crocodile, and differs entirely from its position in the other lacertæ. The effect of this is to give to all this part of the head a contour at first sight strikingly similar to the former, and most completely dissimilar to the latter.

A fossa, evidently connected with the external opening of the tympanal cavity, may be distinctly seen in the head represented fig. 8. Pl. XVI. between *o*, *p*, and *n*; and, although the bones are slightly displaced, may be traced in the head represented Pl. XVII.*—It will be seen, on comparison, to agree very nearly with that of the crocodile, being surrounded posteriorly as well as anteriorly by the neighbouring bones; whereas, in the other lacertæ, the posterior inclosure is formed by membranes only. The mastoid process (*n'*), which completes the inclosure posteriorly in the Ichthyosaurus, appears to be a separate bone: in the crocodile it is united to the squamoso-zygomatic bone (*n*); in the lacertæ it is separate, but very differently placed.

VIII. Occipital Bones.—So far as I am able to judge from the inspection of numerous specimens, the structure of the occipital part of the head agrees with

* In this specimen the squamoso-zygomatic portion of the temporal appears to be broken off; and the upper extremity of the os quadratum, together with superior and lateral occipitals, are forced outwards. The mastoid process however (*n'*) is nearly in its true place.—See the description of the Plates.

the sketch in the margin; but never having seen the part entire in any single specimen, I have wished to keep this representation distinct from the delineations of actual specimens which accompany this paper; intending it only to serve as an index to the detached bones represented in the Plates; and offering it only as an attempt to restore the part conjecturally.



First we may notice the posterior face of the os quadratum; this bone is well exhibited in the back of the head represented fig. 8. Pl. XVI.; and presents the outline given in the annexed sketch. A sort of wing-shaped process (*o'*) runs back from it towards the inferior occipital (*r*); but this part is rather obscured by pyrites, and it cannot be clearly ascertained whether this process may not be a separate bone united to (*o*) by a suture.

The inferior occipital (*r*), bearing the condyle, is frequently found in a detached state: three figures of it are given in Pl. XX. fig. 2.:—where *a* is a view of the exterior surface; *b* is a lateral view; *c* is a view of the interior surface. It is shown, beneath the temporal bone (here crushed in upon it) in Pl. XVI. fig. 8.; and close to the posterior part of the pterygoids in the head figured in Pl. XVII.

The superior (Q) and lateral occipitals (*ss*) I have only observed in one specimen; namely, the head which is figured in Pl. XVII. They are there slightly displaced, but may at once be recognised as surrounding the top and side of the foramen magnum.

The whole configuration of the occipital portion of the head, especially the manner in which it is connected with the os quadratum, bears a much nearer analogy to the crocodile than to the other lacertæ. Some of the separate bones, however, approach more nearly to those of the latter; the superior occipital, for instance, in the crocodile, does not extend low enough down to form the upper margin of the foramen magnum; but in the ichthyosaurus it appears to do so, as in many lacertæ.

IX. Palatal Bones, Pterygoids, &c.—These parts are exhibited in a very satisfactory manner in the beautiful specimen figured in Plate XVII.

This specimen seems to me clearly to prove that the arrangement of this part agreed in all essential points with the crocodile, and differed from the lacertæ; as will appear by the following detail of circumstances:—

1. The maxillary bones (*b b*) are close together, so as to form a solid roof to the mouth.

2. The palatal bones (*e e*) and internal pterygoids (*f f*) are likewise close to each other, so as to form a floor below the nasal canal, and thus throw its posterior opening far back.

A greater solidity is thus given to the whole appearance of this part, and the position of the posterior opening of the nasal canal must affect the functions of respiration.

I cannot discover in this specimen traces of the external pterygoids; which were figured in my former paper on the authority of a specimen that was rather dislocated, and might have exhibited deceptive appearances. It now appears, that the narrow form which that specimen assigned to the palatal bones, must have arisen from its presenting only an impression of them where they project into the nasal canal.

It would still be desirable, in order to complete our knowledge of the skull of the ichthyosaurus, to procure a series of sections through its posterior part, such as might lay open the internal arrangement of the bones, especially of the sphenoid. Mr. De la Beche, whose local opportunities in examining specimens are great, will keep this object in view, and the result will at some future time be submitted to the Society.

The notices above given point out all the analogies derived from the osteology of the head. To these it is to be added, that the structure of the humero-sternal part bears decidedly a nearer analogy to the lacertæ than to the crocodile; since the clavicular furcula is wanting in the latter genus.

X. Vertebræ.—I have only to add to my former remarks on this part of the skeleton, that the atlas and axis agree exactly with the other vertebræ, as is the case in fish. The statement that these parts appeared to resemble the atlas and axis of the turtle, arose from my having taken a mutilated portion of the occipital condyle, in a dislocated specimen, for the inferior portion of the atlas.

XI. Extremities.—A more perfect representation of the paddle than has yet appeared is given in Pl. XX. fig. 1. This will at once show the exact manner in which the series of bones succeed each other.

PLESIO-

PLESIOSAURUS.

The researches of Mr. De la Beche, during the last year, have not been crowned with the success of meeting an entire skeleton of this new genus; but many important parts have been brought to light.

The first of these is a very perfect dental bone of the lower jaw, which is represented under three points of view in the figures of Plate XVIII, being there one half the natural size. We may with great certainty ascribe this to the plesiosaurus: for it certainly belonged to some animal which had a composite jaw like the Saurians; since the posterior end of the bone thins off too much to have formed part of a single maxilla. Again, in the lias at Lyme, the only vertebræ of size enough to have belonged to such a jaw are those of the ichthyosaurus and plesiosaurus. It is probable, therefore, that it belonged to one of these; but the dental bone of the former is well known, while that of the latter (till the occurrence of the present bone) had never been found. It cannot with probability be objected that it might have belonged to some third animal so rare that its vertebræ have not yet been met with; for fragments of a similar dental have in other instances been found: so that the suspicion of extreme rarity, which might have attached to a single specimen, is precluded. On the whole then the evidence stands thus:—We find in the same place skeletons of a Saurian animal wanting the jaw, and the jaw of a Saurian animal wanting the other bones; and no other claimants exist for either.

This dental bone resembles that of the crocodile more than that of the other lacertæ. The teeth which, with the exception of one young tooth, have unfortunately been displaced, were lodged in separate alveoli; on the inner side of those alveoli is a series of small holes, designed apparently for the passage of nerves and vessels (as in the crocodile); and along the outer side of the jaw, dispersed irregularly in small points, are holes for the passage of the branches of the lower maxillary nerve, which is the case in the crocodile also, as contradistinguished from the other lacertæ.

Head.—Of the head of the plesiosaurus, only a single specimen approaching to completeness has yet occurred; which was discovered by Mr. Thos. Clarke in the Lias of Street near Glastonbury. It is represented in Plate XIX.* This specimen is unfortunately much crushed; but is nevertheless sufficiently perfect to exhibit its most essential osteological characters.

* In this and in the former Plates the same letters have been employed to designate the analogous bones.

These characters, when viewed collectively, present, as might have been expected, an assemblage *sui generis*. Taken separately, they exhibit partial approximations to the ichthyosaurus, the crocodile, and the other lacertæ; nor is there any part of the structure of this new genus which may not be paralleled from one of these three types. But I should be inclined to pronounce (though not without hesitation) the approximations to the latter class to be most close and important.

In its general contour, the character of its temporal fossæ, and the position of its ossa quadrata, this genus resembles the lacerta iguana, &c.: but the small size of the nostrils, the conformation of the palatal and pterygoidal parts of the roof of the mouth (so far as the specimen enables us to judge of them), and the dentition, remove it from this type.

It agrees with the ichthyosaurus in the position and small size of the nostrils, and in the structure of the palatal and pterygoidal parts; in which last respect both the one and the other approximate to the crocodilian type; but it differs in the comparative shortness of its snout, which gives an entirely dissimilar character to the whole contour of the head; in carrying its teeth in distinct alveoli instead of a continuous furrow; and in all those points which we have mentioned as peculiarly resembling the proper lacertian type.

The only circumstances of peculiar analogy with the crocodile, are the dentition (as before stated) in distinct alveoli, and the distribution of the holes in the maxillary bones giving passage to the branches of the maxillary nerve.

Like the ichthyosaurus, then, this animal seems in a certain degree to have blended the characters of the lacertian branch of Saurians, properly so called, with those of the crocodile, and to have been in the same manner distinguished from all recent Saurians by an inferior development of the olfactory organs.

I proceed to a more detailed examination of the specimen represented in Plate XIX.—

Dentition.—The teeth are conical, very slender, curved inwards, finely striated on the enamelled surface, and hollow throughout the interior; they most nearly resemble those of the crocodile, but are still more slender: the specimen being obviously a young individual, it is impossible to determine whether the teeth continue hollow in age, nor are there any appearances which indicate the manner in which the secondary replace the primary teeth. The eight anterior teeth are considerably larger than the rest.

Lower jaw.—The dental bone (*u*), although well exhibited in this head, is yet so much more perfectly displayed in the larger specimen, figured in Pl. XVIII. that we have only to refer to our description of that specimen.

The opercular bone may be seen as a lamina lining the interior of the dental.

The suture dividing the coronoid bone (x) and the angular (v) may be traced in the posterior part of the jaw. The coronoid process is not visible.

The articular bone (y) seems considerably more developed than in the ichthyosaurus and crocodile, and to approximate more nearly to the corresponding part in the proper lacertian type.

The lower jaw further agrees with the lacertian type, in the absence of the oval hole which characterizes the recent species of crocodiles.

Upper jaw, and sutures of the head.—It is very difficult, from the crushed state of the specimen, to ascertain the exact situation of the sutures dividing the component bones of the head. The intermaxillaries (a) appear to occupy a considerable space in front of the nostrils; the maxillaries (b) to exhibit only a small portion exteriorly. The nostrils are small, and placed as in ichthyosaurus; the sutures dividing the nasal (k), lachrymal (i) and frontal bones (Hhh') are indistinguishable; and the outline of the orbit has been entirely distorted by the compression the specimen has undergone. The jugal bone (c) is tolerably distinct, and the suture dividing it from the posterior frontal (h') may be traced; the branches of the parietal (m), and the temporal (n) surrounding the temporal fossæ, are sufficiently clear. The structure of all these parts closely agrees with that of the lizard, iguana, &c. The os quadratum (o) is suspended as it were by its articulation to the temporal (n), as in the above genera, and not solidly fixed by an insertion among all the neighbouring bones as in the crocodile, and probably in the ichthyosaurus.

Traces of the occipital and sphenoidal bones may be seen, but in a state so much mutilated and distorted, that it is absolutely impossible to form any judgement concerning these parts. Within the left temporal fossa part of a slender cylindrical bone may be observed, which is probably a fragment of the long columnar process uniting the sphenoid to the parietal; a structure peculiarly characteristic of the lacertian type. The palatal and pterygoidal bones are very obscurely shown; we have only ventured to indicate these parts by dotted lines.

The accompanying Plate represents,

Fig. 1. A view of the specimen, placed so as to rest on its upper surface: this exhibits the whole of the right lower jaw, and the jugal and temporal bones and os quadratum of the same side.

Fig. 2. A view of the specimen, placed so as to rest on the lower jaw, and thus exhibiting all the upper part of the head.

Fig. 3. A single tooth, rather magnified, and split, so as to show the interior cavity.

Fig. 4. An attempted restoration of the head, to assist the eye in tracing the connexion of its parts: A. viewed on the side; B. viewed from above. The

data are sufficient to render this restoration a very close approximation but the sutures between the bones, being in many instances doubtful, are indicated only by dotted lines.

On the whole, then, the manner in which the ribs of the plesiosaurus articulate, throughout, by a single head, to the extremity of the transverse processes of the vertebræ only,—the structure of the humero-sternal parts,—and the characters derived from the head, approximate this animal most nearly to the lacertæ. By its teeth, on the other hand, it is allied to the crocodile: while its small nostrils and multarticulate paddles are features in which it resembles the ichthyosaurus.

In Plate XXI. fig. 1, 2, 3, is represented the posterior portion of the lower jaw of some saurian animal, perhaps the plesiosaurus, found in the lias at Weston, near Bath, by Colonel Birch. With it was found the bone, figures 4, 5, 6; probably an humerus, but very different in its contours from those of the plesiosaurus which we had previously met with. Perhaps it may be a new species; but as it probably belonged to the same individual with the jaw-bone accompanying it, we cannot speak with certainty of either.

Colonel Birch has lately procured two specimens, which exhibit the humero-sternal parts of this animal *in situ*. They confirm the place we assigned to these bones, as figured in our former memoir; but we still wait for more illustrative specimens before we endeavour to figure the whole of this part. At the point of the clavicular furcula there appeared to be a complex apparatus of bones, probably a regular sternum; but this part was too much fractured to be much relied upon. The coracoid bones had a somewhat greater length, from their anterior to their posterior tip, than those before figured; but as they belonged to an animal of much greater size, the proportion may perhaps be modified in age.

Attached to one of these specimens, was a series of vertebræ exhibiting the cervical, dorsal, and lumbar vertebræ *in situ*: this was important, as confirming the position assigned to those figured in the former paper, which were loose, and had been often deranged; the arrangement assigned to them is however in every instance confirmed by the series now mentioned.

In Plate XXII. are figured an *os ilium?* fig. 3; an *os pubis*, fig. 2; and a femur, fig. 1; all found with other bones of the plesiosaurus. From the inspection of specimens in which the humerus and femur have been found together, it appears that they are both much of the same size; so that probably in this animal the difference between the length of the anterior and posterior extremities, observed in the ichthyosaurus, does not exist.

I shall conclude these details by noticing a series of vertebræ discovered in the Kimmeridge clay near Weymouth, and exactly corresponding to specimens found in the same formation in Headington pits near Oxford. They appear to belong to a species of plesiosaurus, as will be seen by comparing them with the vertebræ figured in the former memoir. There is this great difference, however; that in the plesiosaurus of the lias, the length of the side in the cervical vertebræ is greater than in the dorsal; in these the proportions are reversed: the latter are figured in Plate XXII. fig. 4 to 7, and may be thus compared with the series before given in Vol. V.—

Fig. 4, Plate XXII. of the present communication	with fig. 4 & 5, Plate 41, Vol. V.
Fig. 5.	with fig. 6. ....
Fig. 6.	with fig. 7. ....

Fig. 8. will be found exactly to resemble the ordinary form of the middle dorsal vertebræ in the plesiosaurus.

These vertebræ are more than three inches in diameter, yet the annular part has not anchylosed to the body.

I cannot conclude these observations without appealing to the reader's indulgence, as well on account of the nature of the subject, as of my own inexperience in the branch of science to which it relates. To the observer—actually engaged in tracing the various links that bind together the chain of organized beings, and struck at every instant by the development of the most beautiful analogies, almost every detail of comparative anatomy, however minute, acquires an interest, and even a charm; since he is continually presented with fresh proof of the great general law, which Scarpa himself, one of its most able investigators, has so elegantly expressed—"Usque adeo Natura, una eadem semper atque multiplex, disparibus etiam formis effectus pares, *admirabili quâdam varietatum simplicitate* conciliat:"—Yet when these very details are reduced to the technicalities of language, and when a perpetual struggle against the difficulty of conveying clear ideas of the relations of form through the medium of words, is to be sustained, they must often unavoidably appear dry and tedious. I need not add how much these difficulties will be increased in the hands of a writer, who must acknowledge that, while intruding on the province of the comparative anatomist, he stands on foreign ground; and, using almost a foreign language, is frequently driven to adopt an awkward periphrasis, where a single word from the pen of a master would probably have been sufficient.

X.—*On the Valley of the Sutluj River in the Himálaya Mountains.*

By H. T. COLEBROOKE, Esq. F.R.S. F.L.S. V.P.G.S.

[Read December 1, 1820.]

THE Satrúdá or Sutluj river, taking its source in the lake of Ráwan, contiguous to the celebrated Mánasaróver, within the Himálaya mountains, descends through a long valley of that lofty range, in a westerly and south-westerly direction towards Hindustán*. It issues from the Himálaya, at a distance of fourteen miles from Rámpúr, the capital of Basahar: the mountainous chain runs north-west towards Cáshmír; and the river cuts it at half a right angle. The subsequent course of the stream traverses a hilly tract of less elevation, comprising a part of Basahar with Handúr and Calúr (of which the capitals are Biláspúr and Palásiya); until finally it emerges into the plain of Hindustán.

Within the snowy mountains the valley of the Sutluj bears the name of Khanáwer: which designates a tract of country extending eastward to Shipkí, the frontier town of the Chinese territory,—and northward to Shiälcar, a fort of Basahar, upon the borders of Latác, on the banks of the river Lí, which joins the Sutluj under the village of Namgïa, the last of Basahar.

The Lí, nearly equal in size to the Sutluj, has its source south of Leh, the capital of Latác. Its course is southerly to its confluence with the Sutluj.

The district of Khanáwer, or middle valley of the Sutluj, stretches twenty-five miles along the banks of the Lí to Changó and Shiälcar.

The upper valley of the Sutluj, from its source in the Ráwan-hrad to the town of Shipkí, lies within the Chinese territory. A considerable portion of it was seen by Mr. Moorcroft in his journey to the Mánasaróver, a narrative of which is published in the twelfth volume of Researches of the Asiatic Society.

* The map (Plate XXIII.) intended to illustrate this Paper was sketched by Mr. Webster, under the direction of Mr. Colebrooke, from various documents. The connexion of the valley of the Sutluj with the rest of India, is shown in Plate XXIV.—In the word *Sutluj* the last syllable is to be pronounced as if written *-ledge*, or *-ludge*,—*Sut-ludge.*

The lower valley of the Sutluj, from the spot where it bursts from the Himálaya, until it reaches the flat country, is easily accessible to examination and research.

The middle valley, comprising Khanawer, had been visited by Capt. Hodgson in June 1816. It has been explored by Lieut. A. Gerard, assisted by his brother, in the progress of a geographical survey on which they were employed in the autumn of 1818. The narrative of their route has been communicated to the Asiatic Society, and will be inserted in the fourteenth volume of that Society's Researches. Their geological observations and collections, purposely made for me, at the instance of Dr. Wallich, a member of this Society, have been obligingly communicated; and enable me to lay before this meeting the geological specimens collected by them, with satisfactory information as to their local position, whence conclusions may with confidence be drawn regarding the general structure of the country.

Too much praise cannot be given to the indefatigable exertions of those gentlemen; who, while engaged in a laborious survey and arduous journey, had zeal and perseverance to devote unceasing attention to geological inquiry, under circumstances most discouraging.

They laboured under the disadvantage, as Lieut. Gerard modestly expresses himself, of being unacquainted with mineralogy: yet an ample collection of specimens was every day made. The greater part of these was however lost; and not a few mixt and confounded by the carelessness of servants; notwithstanding the precaution of originally putting the specimens in separate covers, with the names of the places where they were collected distinctly specified.

At the three highest peaks visited by them, 16,921, 18,493, and 19,411 feet above the level of the sea, they picked up a number of different stones: but as the ascent was upwards of 7000 feet in each instance, and extremely fatiguing, not to mention excessive debility and severe head-ache experienced at those great elevations, it is not surprising that the attendants to whom the specimens were handed, often threw them away as fast as they were collected: and neither threats nor entreaties could prevail with the people to carry more than a very few.

The three days employed in visiting those high peaks, as Lieut. Gerard observes in a letter to Dr. Wallich, were truly disastrous. Thermometers, barometers, perambulators, and theodolites were broken in pieces. The temperature was 22° below the freezing point of Fahrenheit at half-past four p.m., and they had near 8000 feet to descend, over the most frightful road, to reach their camp. The people threw away every specimen collected: the surveyors were themselves burdened with their instruments and journals, which they would not trust in other hands. Night overtook them, and they lost their road. Most of their servants passed the night at a great elevation without fire; and next day few of them could move, owing to soreness of their feet. These circumstances, he goes on to say, will account for the few varieties of rock and the smallness of the pieces collected at different places.

In another letter he remarks, that, owing to the length of the daily marches, and the requisite attention to the trigonometrical survey of the valley, the barometrical altitudes and geometrical measurement of peaks of the Himálaya, observations of the limit of snow and congelation, and of the nature of the rocks,—they found it impracticable to devote more attention to the riches of the vegetable and mineral kingdoms. In saying that they noticed the texture and disposition of the rocks, he implies only the general appearance of what constituted the base of the line of route, picking up fragments that lay upon the way, without the application of a hammer,—which unfortunately was lost.

The primary object of the journey was, to approximate towards the extreme height of Mánasaróver by barometrical measurement of the bed of the Sutluj, at the furthest limit of their advance; observing in their progress the gradual rise, direction, and diminution of the bed; taking latitudes and longitudes of places, and determining positions of villages and line of route. These objects occupied their foremost thoughts, and, without the expense of that time which was due to those prominent objects, they could not well have obtained more success in their geological collections.

Wearied by a daily march of eight or ten and sometimes twelve hours with only a single halt during a month and a half, having no conveyance but their own feet, travelling by rugged roads over stupendous mountains, they were compelled to leave many things undone. The survey of the route and measurement of heights occupied generally their whole time from sunrise to sunset; after which they were employed till midnight, taking astronomical observations and gathering information respecting neighbouring countries.

I quote these apologies on account of the interesting picture drawn of difficulties encountered: but an excuse was unnecessary; for, notwithstanding the loss of many specimens, and the confusion which unfortunately has crept among not a few of those preserved, a great number remains; which having received safely, I have now the gratification of presenting to the Geological Society.

The specimens to which I shall first draw the attention of the Society are from the lower valley of the Sutluj; taken from the banks of that river, between Kángal and Súniya, at the elevation of 2000 feet above the level of the sea. The banks of the Sutluj are there composed of limestone, apparently primitive.

The general inclination of the strata is stated to be ten or fifteen degrees, and the direction much diversified.

At Jaurí, on the northern bank of the Sutluj, in the vicinity of the places above mentioned, or nearly half way between them, hot springs issue at so small a distance as two or three feet from the river. They are eight or ten in number. A thermometer plunged into one of them rose to $130\frac{1}{2}°$ Fahr., while the temperature of the river was 61° on the 11th of October. The water bubbles up among small pebbles, has a strong sulphureous smell and very disagreeable brackish taste, and encrusts the stones with a yellow substance (Qu. sulphur?).

Gold-dust is found in small quantities, among the sands of the river, near this place.

The next specimens for notice are from the Gisigangá, a stream tributary to the Jamuná. The banks of that river for many miles, between Kúrlá and Sermúr, consist of limestone, and of a rock containing chlorite and mica. The bed of the river in that part has an elevation of 1500 to 2000 feet above the sea.

Among the specimens is a stalactite, from the roof of a cave near the top of the Caról mountain. The cavern is situated about 6500 feet above the sea. Mr. J. B. Fraser likewise, in the narrative of his journey through the Himálaya mountains*, has noticed the Sein range of hills, on the right bank of the Girigangá, as formed of calcareous stone.

It appears then, that limestone is prevalent in the lower hills, which adjoin to the Himálaya, and are contiguous to the lower valley of the Sutluj.

From the valley of the Páber river, another tributary of the Jamuná, specimens have been furnished. One from the banks of that river, near Cshírgaon, at an elevation of 6000 feet above the sea: it is gneiss. Another is from the confluence of the Páber and Sísún rivers, at an elevation of 8350 feet above the sea. The rock consists of gneiss.

Lieut. Gerard crossed the Himálaya at the Brúáng pass, to enter the middle valley of the Sutluj. It is the route of communication between this valley and that of the Páber. Its extreme altitude is 15,100 feet above the sea. A variety of specimens was collected at this pass. They consist of mica-slate, gneiss and granite; some of them containing garnets; others tourmalin. Veins occur of quartz and mica, and of quartz and hornblende.

The travellers proceeded along the left bank of the Sutluj to Puárí and Rispé, at which last-mentioned place they met Lama priests. Thence they

* 4to, London, 1818. See also Geological Transactions, Vol. V. p. 60, &c.

advanced to Marang, a large town upon the left bank of the Sutluj, at an elevation of 8500 feet above the sea.

The Bespá river, a tributary of the Sutluj, falls into it ten miles north of the Bruáng pass. At the station of Puárí, near the confluence of those rivers, the mean height of the bed of the Sutluj is 6300 feet above the level of the sea. The stream flows over rounded pebbles of granite, with sand. The rocks, which constitute the banks, are inclined to the horizon at an angle of twenty-five or thirty degrees, and dip to the eastward. From specimens collected there, they appear to consist of granite, gneiss, quartz compact and granular, and quartz with mica.

The valley of the Baspá river has been recently visited, that is, in October 1819, by Lieut. Herbert, the companion of Captain Hodgson in his arduous survey of the Ganges to near its source above Gangáwatrí. He crossed the ridge of the Himálaya by a pass which is situated between the cataracts at the head of the Rúpin river and the sources of the Baspá. The elevation of the pass was ascertained by him, according to Archdeacon Wollaston's method, and determined at something more than 15,000 feet. Snow lay on its acclivity, and no vegetation was observed; unless the discoloration of the rock implies the presence of lichens. Mr. Herbert remarks, that nothing was visible but bare black rock crowned with snow.

Between Puárí and Rispé, from 6500 to 9800 feet above the sea, the rocks, most part of the way, are formed of a whitish crumbling granite. The Cailás or Raldang mountains on the south, an assemblage of pointed peaks covered with snow, and more than 20,000 feet above the sea, appear to be composed of the same kind of rock; viz. whitish granite. The specimens collected in this portion of the route exhibit granite and gneiss.

In the bed of the Tídong rivulet, two miles east of Rispé, are found quartz rock, and granite containing tourmalin. The bed of the rivulet is 7,600 feet above the sea. The rocks near this consist of mica-slate, with tortuous veins of white granite, of various breadth, running in every direction.

Overhanging the town of Marang is a mountain of clay-slate. Upon it, at an elevation of 12,000 feet, heath, juniper, and gooseberry bushes were growing.

The travellers, proceeding to the Túngrang pass, observed the rocks on the way, chiefly formed of compact quartz with chlorite. The pass itself, which is 13,740 feet above the sea, and is connected on the south with a group of snowy peaks about 20,000 feet in height, exhibited clay-slate with pyrites and with mica.

A greater variety of specimens was collected a few miles further, between

Nisang and Keipú-ghát. The strata, according to Lieut. Gerard's observation, run north-west and south-east, and dip to the north-east at an angle of forty or forty-five degrees. The height is from 9000 to 13,500 feet above the sea. The specimens there collected exhibit granite, gneiss, mica-slate, cyanite with quartz and mica, actinolite and quartz with garnet, pyrites in quartz, limestone (blueish-grey with white veins), and calcareous tufa.

The route led next to a spar bridge over the Sutluj, at Namptú, passing by the way a rivulet named Hóchó. Between that rivulet and Námptú-sángó, at heights of from 8200 to 11,400 feet above the sea, granite with and without tourmalin, gneiss, mica-slate, drawing-slate, and clay-slate with imbedded specks of sparry iron-ore, were found. The bed of the river is 8220 feet above the sea. It exhibits only two sorts of rock,—mica-slate, and granular quartz with imperfectly crystallized hornblende.

The progress of their survey conducted the travellers, over rocks of gneiss and granite containing tourmalin and garnet, to Namgïa, at the confluence of the Lí river and Sutluj. The banks of the rivers at their confluence consist of granite. Further up the Lí river, the banks of it present slate, potters'-clay, marl or loam, and sand. Among specimens here collected occur flinty slate and stalactitic carbonate of lime; gypsum of a yellowish-white colour and fine granular texture, and white granular anhydrite. Still higher up the same river, in the vicinity of Changó, a place situated on the left bank of the river, where its bed is no less than 9900 feet above the level of the sea, the specimens collected exhibit primitive granular limestone, with disseminated pyrites; also mica-slate, with what appears to be part of a vein of granite.

Between Namgïa and Shipké, a town situated on the Sutluj, where the channel of the river is 9000 feet above the level of the sea, the rocks consist of granite with and without tourmalin and garnets, gneiss, mica-slate, compact quartz, quartz and mica with cyanite, and some steatite.

This town, or collection of tents, is within the limits of Chinese territory and terminated the survey eastward. The travellers however visited Shipke-ghátí, a pass to the westward of north from the town. The height of the pass exceeds 13,500 feet above the sea; and at the summit specimens were collected, among which there occur gneiss with hornblende, cyanite in quartz, and a substance much resembling cinnamon stone in mica-slate, and with felspar and mica.

North of this pass is the Tarhígang mountain, which Lieut. Gerard ascended to the prodigious height of 19,411 feet above the level of the sea. The summit of the mountain, concluded to be 22,000 feet high, was less than two miles distant from the station which they reached. Two specimens have been preserved which were found at that station: one is granular limestone, the other granite with tourmalin and garnet. The stones lie there in immense detached masses, heaped upon one another in frightful confusion.

Eastward of that pass, in the bed of a rivulet named Rípsáng, at the height of 11,000 feet above the sea, a number of specimens were collected, comprising granite, gneiss, mica-slate, quartz and tourmalin, and calcareous tufa. The rocks on either side of the rivulet are precipitous, composed of varieties of loose stones piled upon one another in wild disorder.

Northward of the Sutluj, between two ranges of the Himálaya, in the route of the survey returning westward, specimens were collected between Sángnam and Labrang, which consist of clay-slate, quartz rock, and a stone very like compact felspar, with mica, and compact limestone of a smoke grey colour and splintery fracture.

Between Rárang and Pangí, gneiss, and granite with and without tourmalin and garnet, occurred.

Between Pangí and Rógí gneiss was found. Between Rógí and Mírú grey granite was noticed. Between Mírú and Wángtú both granite and gneiss were the rocks observed.

In the bed of the Sutluj, at Wángtú, where a bridge of ropes has been thrown across the river, the rocks consist of granite and gneiss. The channel of the stream at this place has an elevation of 5250 feet above the sea.

The Ról or Shátúl pass over the Himálaya mountains, the route by which the surveyors returned from their arduous journey, is nearly 15,000 feet above the sea. The rocks at its summit consist of gneiss. The peaks on either side, rising to an elevation of nearly 3000 feet more, appear to be formed of the same rock. The rocks on the southern face of the Himálaya descending from the Ról pass, at the height of 12,000 feet above the sea, are ascertained to be generally composed of gneiss. On the northern face of the mountains ascending from the Sutluj to the Ról pass, the prevalent rock was found to be granular quartz. It lies in immense compact masses.

Besides the specimens which have been noticed, with reference to the precise spots where they were collected, a considerable number has also been received which had been mixed and confounded; but which Lieut. Gerard believes to have been collected by him in his progress along the banks of the Sutluj, between Rispé and Marang, Keipú-ghát and Hóchó-nadí, Namgïa, and Nákó. They consist of granite, gneiss, mica-slate, clay-slate, compact quartz with chlorite, and primitive limestone. Several of the specimens of granite contain crystallized tourmalin and garnet; and also a rolled pebble of compact smoke grey limestone. In one instance an alluvial aggregate occurs.

I have enumerated the specimens forwarded by Lieut. Gerard at some length, and connected with them the information supplied by his letters and memoranda communicated to me, for the sake of authenticating the geological facts which are ascertained in this way, by means of researches conducted without previous knowledge of the science. I need hardly add, that the primitive character of these lofty mountains, at every spot visited, is precisely what was to be expected.

It is worthy of notice, that throughout the tract explored, granite, gneiss, mica-slate, quartz rock, and limestone, appear every where alternating with each other; and that limestone, as well as granite, was picked up at the greatest elevation which was attained.

Though the topic be unconnected with the immediate subject of this paper, I cannot quit Lieut. Gerard's letters and memoranda without quoting from them the very surprising circumstance, that seeds of a species of campanula were gathered by him at the elevation of 16,800 feet above the level of the sea; on a spot where the temperature was 27° of Fahrenheit's thermometer at noon in the middle of October. The latitude was nearly 32° north. Shrubs were found by him in a vegetating state still higher.

XI.—*On the Geology of the North-eastern Border of Bengal.*

By H. T. COLEBROOKE, Esq. F.R.S. F.L.S. V.P.G.S.

[Read January 5, 1821.]

THE information which I now lay before the Society is chiefly, and almost exclusively, grounded upon communications received from Mr. David Scott, Commissioner at Cooch-Behar in Bengal, who has obligingly furnished specimens of the rocks collected by him in his visits to divers parts of the district under his authority, and liberally communicated observations made by him on the spot. They are valuable as the genuine remarks of an attentive observer, not indeed profoundly skilled in geology, but divested of all bias of preconceived opinions: and I use his communications with entire confidence.

The specimens which have reached me were collected near the north-east corner of Bengal, where more than one river of note, issuing from the bordering mountains, enter the plain.

The Brahm-putra, a river which meets the principal and eastern branch of the Ganges at no great distance from their common junction with the sea, emerges from the mountains at the north-east angle of Bengal, after a long course in the Himálaya. The hilly country, which it last traverses, is Asham, rarely visited and little known. Our acquaintance with its geological character is confined to the mountains that give passage to the Brahm-putra, thence issuing into the plain.

On the northern bank of the river in that position is a hill at Jogigopa, which is connected, not however without some breaks or intervals, with the Bhotan mountains. The body of the hills consists of a large hemispherical mass of gneiss. On either side of it is granite; graphic granite on the one hand, and granite of a different character and middling-sized grain on the other. The last-mentioned rock is in nearly vertical masses (Mr. Scott terms them strata), the direction of which is from north-east to south-west. Toward the west graphic granite occurs, on the top of a large mass of gneiss. It appears to be divided by transverse fissures into rhomboid forms; a few cracks crossing the rhombs diagonally.

Paglanát'h is a hill on the south side of the Brahm-putra, being the north-western extremity of the range marked on maps as opposite to Jogigopa. The rock, in the only place where it is exposed, has been much affected by the weather. It appears to consist of gneiss. The masses (or strata) run from north-east to south-west, dipping to the south-east at an angle of about forty-five degrees. They are crossed by transverse cracks from south-east to north-west, and veins of quartz in some places follow that direction.

At Gwálpárá, some miles east of Paglanát'h, granite is found. Among specimens received from thence, is one which consists of felspar, hornblende and mica.

The Brahm-putra, shortly after its entrance on Bengal, receives from the Bhotan mountains the tributary stream of the Gadádhar, which has its source near Tesisudon. Near their confluence is the hill of Dhabni: it rises not more than thirty or forty feet above the level of the adjacent plain; and the lower portion of the acclivity has been covered by alluvial soil. But on the south-east and north-east sides of it, where it has been cut by the waters of the Gadádhar and Brahm-putra rivers, good sections are observed. The banks are there composed of crumbling gneiss and large-grained granite; in some places intermixed; in others distinct and alternating. The position of the masses (or strata) varies from an almost vertical one to an angle of forty-five degrees; and where they incline, it seems to be to the south-west; that is, they dip to the north-east. The direction is nearly south-east and north-west. On the north corner, the hill terminates in the river in large blocks of gneiss, which are nearly perpendicular where they join the body of the hill. Blocks of green stone, containing metallic specks, apparently of magnetic iron ore, are found in various parts of the bank.

A little lower down, the Brahm-putra receives the Kélankí river from the Gáró hills. It issues from those hills about lat. 25° 40′, and long. 1° 40′ east of Calcutta. At their confluence, and on the left side of the river, a precipitous bank occurs, exhibiting graphic granite and gneiss. This rock constitutes the lower part of the hill. In the bed of the river are found blocks of stone of different sorts; as granite, gneiss, various compounds of quartz and felspar, and quartz united with felspar and hornblende.

On the left bank of the Brahm-putra are the Caribári hills or cliffs. From the confluence of the Cálú, where it comes in contact with these hills, to Mahéndraganj, where they recede eastward, the appearance is nearly uniform. The cliffs in general consist, at the bottom, of slate-clay disposed horizontally. Above this, and in some places below it, there is a stratum of yellow (or, more properly, green) sand, which is often found indurated at the bottom, and accompanied by ferruginous concretions. Over this there is in many places a stratum of slate-clay; and above that the bank consists of sand, white or red, and mixed with gravel. The strata are in general horizontal, or nearly so. No prevailing dip was perceived; but contortions of the strata were remarked, which rise and fall slightly in different parts of the bank, in both directions, as if deposited over an irregular surface. They are in some places entirely interrupted by banks of indurated clay or loam. These interruptions are of small extent; and the horizontal strata soon re-appear on either side of them. In general the uppermost layer of clay coincides in a remarkable manner with the height of the river in the rainy season: but in a few instances it is continued to the top of the bank or acclivity. The lower clay is in many places divided by alternate layers of sand in a very irregular manner: more than eighty alternate layers have been counted.

The general appearance of the cliffs shows the following strata in succession, beginning from beneath; viz. 1st, slate-clay, of the thickness of twelve feet above the lowest level of the river in the dry season: its depth below that level is undetermined; 2d, ferruginous concretions and indurated sand, to a thickness of from three to eight feet; 3d, yellow (or rather green) sand, from three to eight feet: 4th, a layer of slate-clay, of little thickness in general, and wanting in many places: it corresponds to the height of the river during floods; 5th, sand, with small stones or gravel, from twenty to fifty feet.

In different parts of the cliff there have been found clay iron-stone, coarse-grained sandstone, iron-stone concretions, nodules of slate-clay and fossil wood. The clay iron-stone occurs in the coarse-grained sandstone, a bed of which of small extent was observed in one place. The nodules are found in a discontinuous but horizontal layer in the stratum of clay; they are compacter lumps of it. Blocks of fossil wood were met with upon the indurated sand, and were thought by Mr. Scott to have fallen from a higher position. They lie upon a ledge of the bank, which, being of firmer texture than the layer of sand above, has better resisted the action of the river encroaching on the banks. Apparently they belonged to an upper and looser portion of the same sandy stratum.

Mr. Scott likewise found pieces of fossil wood, among shells and other animal exuviæ, in a very singular bed of organic remains discovered by him. It is situated under a small hill in the cliff (rising about twenty feet over the general elevation), and lies about seven feet below the level of the highest flood of the river. Both above and beneath it are layers of clay; and it rests upon alternate strata of sand and clay. Their extent is small, being interrupted by beds of uniform sand. The spot may be about a hundred and fifty feet, at the most, above the level of the sea.

Among the organic remains found in this singular assemblage of them, many interesting objects occur. In the examination of them, and of specimens of rocks accompanying, I have been assisted by Mr. Clift and Mr. Webster: and I could not, without the benefit of such aid, have taken upon myself the task, or ventured to pronounce confidently on any part of these curious remains.

The portion of sand which is found adhering to many of these specimens, and which is no doubt the same with that termed by Mr. Scott yellow sand, has many of the characters of the green sand that is found, in England and France, lying in beds superior to the chalk. An observation no less curious is, that the clay, with which it is here associated, bears a strong general resemblance, in respect of the animal remains which it contains, to the blue clay of the London and Hampshire basins. Among the remains of fishes,—bony palates and the fins of the balistes are common to the Indian clay and to that of Sheppey; and the shells of Cooch-behar bear a strong generic, if not specific, resemblance to the marine formations above the chalk in France and England.

The fact of remains so analogous being found in places so remote and climates so dissimilar, seems not a little important in a geological view.

Remains of aquatic animals, deposited under circumstances in many respects alike, amidst the same strata, at similar elevations above the height of the present ocean, and manifesting so strong a family resemblance, argue the existence, in the primeval ocean, of like families of animals, diffused through climes where the present races of beings are more dissimilar and limited to a narrower range.

The following enumeration comprises the chief part of the objects found in that deposit which has been laid open in the Caribari Cliffs:—

Sharks' teeth; vertebræ and fin-bone of a shark.

Crocodiles' teeth; vertebra of a crocodile's neck; thigh bone of a crocodile.

Dorsal fin and pectoral fins of a balistes.

Palates of the ray.

Palates of the diodon.

Claw of a lobster?

Vertebræ of a bony fish.

Teeth of a small quadruped.

Teeth of another small quadruped.

Oyster shells, of various species.

Several species of cerythium?

Turritella, one or more species.

Balanus.

Patella.—With some others.

At Harigong, in the district of Caribárí, upon the banks of the Brahm-putra river, the rocks exhibit granite, quartz rock, and a sandstone or conglomerate of water-worn quartz pebbles with argillaceous cement.

Proceeding inland from the river, in an easterly direction, to Robágiri*, a village of the Gárós, distant twenty-five miles, the country consists of hills of sandstone interspersed with blocks, and occasionally larger masses of gneiss, and of a rock composed of felspar and quartz. The beds of the rivulet, north of the village, exhibit white clay; and the hills in that direction are composed of the same clay alternating with white sandstone, in many places containing rounded quartz pebbles, and angular pieces of felspar.

Further north, at a distance of three or four miles, is a mountain more than four thousand feet above the level of the village. Where the rock shows itself, it appears to consist of quartz and felspar without mica.

In the bed of the river, at the foot of the village of Robágiri, a stratum of shell limestone is seen above the clay, and is surmounted by another argillaceous bed, which contains shells of a similar character, but in smaller number. In some places the limestone seems to contain bones: but no perfect specimen has been extracted.

In general the Gáró hills may be described as of two orders. The first, rising to the height of two or three thousand feet, and in some places more, are composed of granite with veins of unmixed quartz beneath, and of pure white felspar towards the summits.

The hills of the second order are seldom above 150 or 200 feet in height. They appear to have been formed, from the first, by the operation of water: the strata being nearly horizontal, and their substance composed of clay, sand, and small stones; red in the neighbourhood of red granite, and white where felspar of this colour prevails.

The granitic character of the upper Gáró hills is continued into Asham: and the semicircular bend which the Brahm-putra river takes on its entrance into Bengal, is round a granitic promontory of moderate elevation, at the foot of which lies an undulated alluvial country. Among specimens received from thence, ferruginous sandstone and also greenstone occur.

Further east, towards Silhet, at a place named Laour, shell limestone abounds. It consists in a great measure of nummulites. Specimens, which were received thence, with the information that the lime, which Silhet supplies to all Bengal, is procured from inexhaustible beds of that limestone at the Laour hills, are in the Society's collection. The fact merits notice, as it indicates a later formation than transition limestone, for nummulites have not been found in that situation.

* Some further details respecting the vicinity of this place, from a subsequent communication by Mr. Scott, will be found among the notices in the present volume,—Article XIII. 6.

Quitting the Brahm-putra and its vicinage, research has been extended westward along the northern frontier of Bengal. The steep banks of rivers present the best and almost the only opportunities of examining the strata: and from two such positions, where good sections are exhibited, specimens have been received.

The Tístá, a river which descends from the Bhotan Mountains and traverses North Bengal, is remarkable for a recent, sudden, and great alteration of its course and channel; analogous to changes which may be inferred from actual appearances to have taken place at remote periods in other instances, in the same and other rivers. The Tístá was visited by Mr. Scott at the place where it issues from the lower range of Bhotan hills. He has furnished a sketch of the cliffs, showing the relative positions of the spots whence specimens of the rocks were taken. They consist of sandstone containing much mica, with coal and shale.

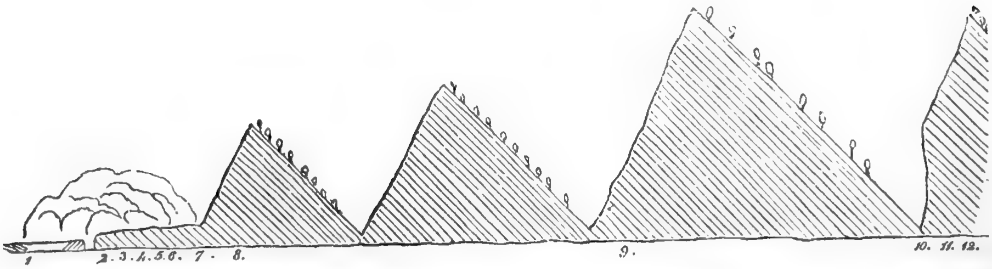
The Súbúk, another river issuing from the Bhotan Mountains, was also visited by Mr. Scott, at the place where it quits the lower hills; and he has furnished a similar sketch of the appearance of the hills as cut by the river. The rock is here quite similar to that which was found composing the banks of the Tístá; and likewise consists of sandstone containing mica, with coal and slate clay.

These hills may be considered to be fair samples of the entire range which skirts the north of Hindustan. They rise to no great elevation, and constitute the first step from the plain of India, ascending towards the mountains of Bhotan and the loftier peaks of the Himálaya. Every where, so far as is yet ascertained, the lower range of hills consists of sandstone, and nearly of the same character, abounding in mica.

APPENDIX.

The following are the sketches communicated by D. Scott, Esq. and referred to by Mr. Colebrooke at the close of the preceding paper: they were accompanied by the specimens described below, collected from the banks of the Tístá and Súbúk rivers, where they issue from the Bhotan Mountains.— The sketches, Mr. Scott remarks, have no pretensions to accuracy, and are merely intended to show the general appearance of the ranges of hills, and to point out the relative positions of the specimens which are indicated by the figures.

On the Tístá River.



The distance from 1 to 12 is about one mile and a half.

The direction of the strata on the Tístá seems to be in general S. 60° W.: but there are a few strata which form an angle with the others, and run about N. 60° W. There did not, however, appear to be any difference in the nature of the rock; and out of twenty-eight strata observed by the compass, only four followed the latter direction. The specimens from the Tístá are the following:—

No. 1. Greenish-grey arenaceous stone of a slaty structure, much interspersed with mica; in strata dipping towards the north, at an angle of about 8° with the horizon.

2. Friable sandstone *, resembling small-grained granite, with traces of a slaty structure; dipping to the south at an angle of 40° (Doubtful whether this was in its natural position).

3. Sandstone of a slaty structure: the plates are thin, and covered with particles of mica:—strata nearly vertical; direction S. 60° W.

4. and 5. Sandstone of similar composition:—strata dipping to the N.W. at an angle of 35° or 40°; direction S. 60° W.

6. A similar compound, of fine grain, with traces of a slaty structure: contains small rounded fragments. Position and direction as of No. 4.

7. Similar compound, of distinct slaty structure; contains pieces of coal and fossil-wood.

8. Greenish-grey soft arenaceous stone, abounding in micaceous particles.

9. Coarse sandstone, containing rounded quartz pebbles of various shades of colour, in a paste like the specimens Nos. 5, 6, and 7, with small pieces of wood

* The specimens denominated *sandstone* in these lists, and to which the term *granitic* may not incorrectly be applied, appear to have been formed from the detritus of granite; the chief ingredients being quartz and felspar, with mica, and a few minute particles of other minerals. The resemblance to granite is in some of the specimens so strong, that where the rounded form of the quartz is not obvious, they are scarcely to be distinguished from certain varieties of that rock.

and coal. This throws much light on the preceding specimens, and explains the nature of their resemblance to granite.

10. Whitish sandstone, much resembling granite, with decomposing felspar.

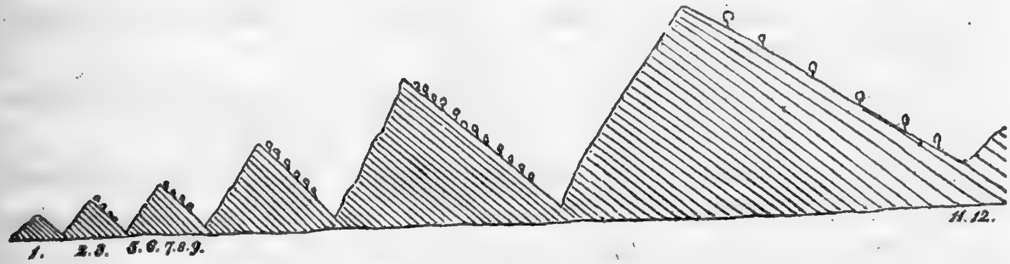
11. Dark smoke-grey slate clay, approaching to bituminous shale, irregularly shot with mica.

The inclination of Nos. 9, 10, and 11, is the same as of No. 4. The direction was not ascertained by the compass, but believed to be from N.W. to S.E.

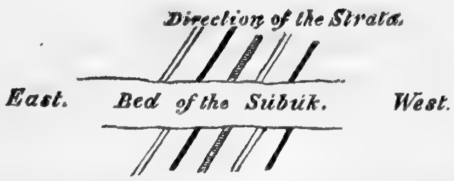
12. Sandstone. In this specimen minute rounded particles of quartz are distinguishable with a lens.

The remaining specimens from the Tístá are portions of blocks found in the bed of the river. They consist of granite, gneiss, quartz rock containing angular fragments of clay slate, greenish-grey splintery quartz with particles of mica, indurated talc, chlorite slate, clay slate,—conglomerates of siliceous pebbles with clay slate, and of clay slate and indurated talc,—sandstone, and two varieties of compact limestone with a splintery fracture, one effervescing copiously with marine acid, the other not perceptibly effervescing till reduced to powder, or till the acid is heated. The blocks from whence these specimens were taken were all of considerable size.

On the Súbúk River*.



The distance from 1 to 12 is about one mile and a half.



On the south side of the Súbúk river the strata seem to enter the hill in the direction of S. 35° W.; but on the north side they appear to run N. 50° E.;

* This river has not been found on any of the maps to which the Secretaries have had access.

and the ends projecting from the opposite banks are generally nearly due north and south of each other, as represented in the lower figure of the sketch*.

The specimens from the banks of this river are the following:—

Nos. 1, 2, and 3. Friable sandstone, much resembling some of the specimens from the Tístá. In No. 2, the rounded form of the grains is evident with the assistance of the lens.—The strata composed of Nos. 1, 2, and 3, dip to the N.W. at an angle of about 35° or 40°: their direction is, on the south side of the river, S. 35° W.; on the north side of the river, S. 50° E.

4. Slaty clay, inclining to bituminous shale, surrounded with coal of a dark brown colour and conchoidal fracture:—found imbedded in No. 5. Probably the cast of part of the stem of a plant.

5. Sandstone like the specimens Nos. 1 and 2. A second specimen, marked No. 5, consists of sandstone, of the same appearance, inclosing small portions of coal, with traces of woody fibre.

6. Sandstone of a grey colour, containing numerous particles of mica, and small portions of coal. The stratum, No. 6, is placed immediately above No. 5. Dip and direction as above mentioned. From the north side of the river.

7. Sandstone, somewhat like Nos. 1 and 2. Dip and direction the same. From the south side of the river.

8. Slaty clay, containing a very large portion of mica; colour greenish-grey: found between Nos. 7 and 9. Resembles No. 8, from the Tístá.

9. From the south side of the Súbúk. Resembles No. 3, above mentioned; and approaches to the specimen, No. 9, from the Tístá.

10. Bituminous shale, with coal;—broken from what appeared to be the trunk of a tree about fifteen feet in length, imbedded in the rock.

11. Bituminous shale;—found under the stratum No. 12, on the south side of the river. A second specimen, also marked No. 11, is soft shale of a smoke-grey colour, precisely similar to the shale of the coal formation.

12. Sandstone, of coarser grain than Nos. 3 and 1: the worn pebbles are here very distinct.

Many of the strata, here enumerated, contain small rounded stones,—often in thin seams, which follow the position and direction of the strata,—and sometimes dispersed through the sandstone, as in the specimen No. 8 from the Tístá.

* The appearances here described indicate the existence of a *fault*, running in the direction of the river.

XII.—*Description accompanying a Collection of Specimens made on a Journey from Delhi to Bombay**.

By JAMES B. FRASER, Esq.

[Read January 13, 1822.]

THE small collection of specimens connected with the following pages, form the chief part of a series, by which I intended to have exemplified the rocks that might occur in a journey from Calcutta to Bombay. But many circumstances, which it is unnecessary to detail, conspired with the insufficiency of the collector's science to render this plan in a considerable degree abortive.

I had particularly to lament my ignorance of Geology, during the first part of the journey from Delhi to Bombay, when our route lay among primitive mountains, full of interest to the geologist. This, no doubt, frequently occasioned my omitting to take specimens where they would have been important, and may have rendered those taken far less valuable than they would have been if more judiciously selected: at the same time I may observe, that it was made a particular object to select only such parts of a rock as were unaffected by exposure; to take a specimen of every new rock that came under observation; and, where possible, to note the junction of different predominating substances; with such other particulars as my own observations, or the instructions I had received from others, induced me to consider worthy of attention. The collection would have been more complete, had I fortunately preserved all that I took; but from the inattention of servants, or from the loss of a whole parcel, it was too late discovered that many of the most valuable were missing, and the extent of the loss I cannot exactly state.

I have purposely omitted adverting to the country through which our route led from Calcutta to Delhi, and to the districts south-east of the Chumbul, fearing to mislead in any attempt to describe them from memory: but what-

* See Mr. Fraser's route in the map, Plate XXIV.—The spelling of the names of places, on the map and in this paper, is the same with that employed in Arrowsmith's large map of India.

ever my obsevations may amount to, will form the basis of another notice, to accompany the specimens from that part of India, when they shall be arranged and presented to the Geological Society.

The country in the vicinity of Delhi, both above and below it, upon the Jumna's banks, and in the Doab * opposite, varies little, if at all, from other parts of the valley of Hindoostan ; but the site of all former capitals of this sovereignty, as well as of the present city, is upon a low and rocky ridge of hills, which ends almost immediately beyond, upon the river bank : nor is there, as far as I am aware, any mass of rock, certainly none of any magnitude or importance, found at this point on the East bank of the Jumna.

This point appears to be the termination, as far as can be seen above the surface, of a range of primitive mountains, connected if not visibly continuous with all those that intersect, and in many parts entirely occupy, the country to the north and west of the Chumbul, and which probably may be found in different parts of the whole peninsula to the southward, as far even as Cape Commorin. Whether the connexion may not be also traced northward, to the Himálaya Mountains, is a point which does not come within the range of this confined notice.

The hills at Delhi are but a ridge, not exceeding one to two miles in breadth, nor any where more than a hundred to a hundred-and-thirty feet high. Taking thence a southern direction, they spread out in breadth ; and increasing in the number of ridges, pass into what is commonly called the Mewat Country ; no where exceeding a thousand feet in height, and generally ranging from three to seven hundred. The height of the hills increases to the southward ; and the fort of Alwur is situated upon the highest point, which may possibly reach 1200 feet. Towards the west and north-west from the vicinity of Delhi, small ridges and insulated peaks run out as far as the southern part of Hurrianuh ; the Hill of Tooham, about sixteen miles to the south of Hansee, being the most northern : it is a single and almost bare rock of red granite, extremely hard, and about seven hundred feet high. There are no hills north of this, to the foot of the Himálaya range, nor westward, to the Indus.

basalt.

From Mewat the hills take a wider spread ; the eastern boundary running nearly in a southern direction, and leaving between it and the Jumna, all the way to the Chumbul, a space of level country which varies in breadth, but is seldom less than forty miles wide. Hills do indeed occur within this space,

* *Dooab* in the Persian language signifies *two waters* : the term is applied to the tract between the Jumna and the Ganges.—Ed.

chiefly of sandstone; but they are evidently of a class and character quite different from, and unconnected with, those in question. On the south-west of Delhi the latter take a south-eastern course, from Hurrianuh to Ajmere; whence they run down more to the southward, but still with an eastern tendency, separating the elevated plateau of Mewar, and the countries to the east, from Mārwaur, Jesselmere, and the lower and more sandy countries of the west; till, at some point not fully ascertained, they are lost in the extensive and elevated trap formations of Malwa, and the countries to the east and southward of that province.

The interior of this wide outline of hills is filled up with a succession of ranges, and valleys, and of plains diversified by insulated peaks or clusters of rocky hills, varying in height and sometimes in character: the ranges of this tract of mountains being seldom continuous with one another above the surface, though every thing declares that they are all connected below. Large tracts it is true occur, which are wholly of a mountainous character; such as great part of Mewar, parts of Jeypoor (or Dhoomdar), and probably several countries to the south-east; but it is only on the western boundary, that the chain assumes its truly mountainous aspect. It will be seen in the sequel, that between Marwaur and Mewar, peaks and mountains occur above two thousand feet high; and to the southward this height may probably be exceeded.

It is remarkable that towards the north, and on the eastern boundary, the hills, though varying little in composition, present a more equal, level-topped appearance, resembling the table-like forms of the trap-formation; no peaks rising above a certain very distinctly defined height: while to the southward, and indeed all along the western boundary, they assume the bold, peaked, and jagged forms of primitive mountains.

The rocks at Delhi are almost entirely composed of quartz: the variety which chiefly predominates having always a tendency to semitransparency and a vitreous fracture, and varying in colour from grey to yellow and red or brown; and this stone appears, by some addition to its component parts or some variation in their admixture, to graduate into sandstone, which is found indiscriminately with it in most parts of the hills: the substance which colours it, also occurring in spots throughout. These rocks are disposed in strata dipping generally towards the S.W. from the horizon, at an angle of about 45°. They have moreover a tendency to division across the strata, as also vertically, so as to produce a cubiform shape. Mica is found occasionally, both in pieces of considerable size and scattered about among the soil; but not, I think, in intimate commixture with the rock itself. The quartzose rock first mentioned is sometimes found of a more granular character; but I could not detect its exact junction with, or transition into, the opake sandy rock.

The old buildings about Delhi, where strength has been the principal object, are almost uniformly formed of this quartzy sandstone; and all the old Hindoo pillars, which seem to have been obtained from the destruction of some temple near the place, and now form part of the Mahomedan buildings around the celebrated tower called the Cootub Minar, are of the same stone: some of these are now passing to decay; assuming often, in such cases, the appearance of coarse grey sugar.

Leaving the chief range of these hills at the Cootub Minar, eleven miles to the south-westward of Delhi, we crossed several lower and less important hills, the tops of which were flat, or rounded, and covered with masses of stone of the same quartzy nature as that above described, the edges and corners being worn off by gradual decomposition, till they had acquired a globular or at least rounded character: scales, as it were, falling off by effect of exposure to the weather. These stones, as well as those at Delhi, are all more or less tinged with iron ore. The hills are very scantily covered with grass and vegetation, and, except in the rains, have a black, gloomy, and barren appearance.

Ten miles on, to the south-west, we entered on a plain alternately sandy and clayey, which, lying between two ranges of hills, extends to Feerozepoor, and indeed a great deal further in the same direction, about S.S.W. Neither range differs much in character or composition from that we had just left, but they rise gradually in height: that to the left-hand takes a direction to the southward of our route; and that on the right increases in width and runs between Rewarrie and Mewat, the valley, properly speaking, in which Feerozepoor is situated and through which our route led.

The hills immediately about this place are probably from four to six hundred feet in height; their tops run much upon a level, without any peak aspiring above the rest, and they are only varied by the water-courses which have furrowed their sides. The predominating rock is granular quartz, nearly the same as that at Delhi; and this forms apparently the whole of the tops of the hills. In penetrating towards their interior, in one of the water-courses (which leads in fact quite through the western range), a more slaty form of quartz was found, occurring in great abundance in a low situation, and apparently occupying the lower and interior part of the range. It is a sort of plum-pudding stone, the cement of which is iron ore, or clay strongly tinged with iron; and it varies considerably in appearance and composition in different situations. The inclosed fragments consist of various substances, generally so large that it was impossible to carry away a good specimen; but I believe they consisted chiefly of the same substances as the surrounding rocks, with a cement of ferruginous clay. This rock is much pervaded with caves and fissures, seemingly of great extent: it is more destructible than the quartz rock, more readily forms soil, and is consequently more overgrown with trees and herbage of all sorts; and it seems also retentive of water to nourish them, for they are greener than in other situations.

The stratification of these rocks resembles that of those we have considered at Delhi; they seem to dip at about an angle of 75° towards the south-west.

On the top and surface of the hills, which are little covered with herbage of any sort, we find a rock which in substance seems to consist of the same quartz, but changed by exposure, and varying in colour; and in some instances worn into cellular cavities.

There is in all these hills a great deal of brown iron ore, which yields a considerable portion of metal, but might produce much more in the hands of skilful smelters; for a great quantity is lost in what is considered only as dross, but which in reality is so rich a slag, that workmen from Marwaur find it worth while to come and carry it away, for the purpose of melting over again.

Continuing our course, we proceeded about twenty-six miles south-west, to Alwur, still considered in the country of Mewat. During this march the hills increased somewhat in magnitude, height, and picturesque appearance, but did not vary in substance or structure. Strata rising beyond the surface, were very conspicuous on various exposures, but it was not easy to detect the dip or general direction: they seemed to be pervaded by numerous veins of fine white quartz. In the plains between the connected ranges, many sharp and insulated peaks, and clusters of peaks (called emphatically by the natives, from their form, *Dauts* or teeth) were observed starting abruptly from the surface, but no doubt connected beneath it with the more continuous ranges that surround them.

At Alwur the hills rise to a greater height, and in many places assume a grander and more primitive character, than those we had left: one singular conical peak, partly detached from the great hill on which the fort is situated, affords a good specimen of the structure of the range at this point. The strata, nearly vertical, but dipping from the horizon towards the east at an angle of 70° to 80°, run in a course little deviating from north and south; they protrude far beyond the surface of the hill from top to bottom: in fact, there is little soil, and the surface consists chiefly of debris from the destruction of the rocks. These strata and all the hills around are pervaded by veins of fine white quartz, running from north to south, and dipping at an angle of about 10°. The prevailing rock is still quartz: but we find in it the same various admixtures of sand, so as to make it approach to sandstone in appearance; the diaphanous sort however predominates, varying in colour from reddish-white to blueish-grey. The veins of quartz are sometimes very numerous; they are irregularly distributed, and vary in thickness from a quarter of an inch to a foot.

The fort of Alwur is situated on the loftiest of these hills, and may be 1200 feet in height from the plain; the highest of the rest do not rise above 1000 feet, but in general they are lower. One of the remarkable characteristics of this portion of the range, its regularity of height, is conspicuous on looking down upon it from the superior height of Alwur fort, from whence all the hills appear to rise nearly to a level, stretching out with this uniform appearance far to the west and north-west, and in fact quite bounding the view in these quarters.

The same range also runs nearly south about twenty miles further, to Rajguhr, which is situated in a basin among the hills on the eastern boundary. The composition and structure do not materially vary; but we found mica-slate in some places, and I was informed that a fine-grained black slate, used in sculpture to adorn their buildings, was found in the vicinity.

From Rajguhr to Amber near Jaypoor, a distance of about seventy miles, in a west-south-west direction, the country varies little from that already described; consisting of sandy plains and valleys deeply indented with water-courses, and uneven in their surface, with a few spots of rich clay or mould, where cultivation is scantily carried on; insulated peaks and clusters of dentated hills, here and there rising from the general level. The rock generally approaches near to the surface, and often appears above it in a state of decomposition, falling into coarse sand, consisting of quartz, mica, and felspar. In passing through a ghat *, about thirty miles from Amber, we saw a single small hill, composed entirely of a white stone, which we were told was marble; and limestone in plenty certainly is found in the vicinity. The other hills differed in no respect from those already described, the strata pointing to the north-east and east, and the rocky faces being chiefly to the south-east and east.

The hills at Amber and Jaypoor do not vary from those already mentioned, but are not so lofty as those about Alwur. The predominating rocks were still quartz and granite; and the stone commonly used in building is granular

* Ghat signifies a mountain pass.

limestone of a light greyish hue, taken from the vicinity of the town: there is none however, we were informed, very near it, of a texture sufficiently fine to be used as marble:—that in most common use, which is taken from twenty to thirty miles to the westward, is grey, veined with a darker shade. All the white marble is brought from Mukrana, a place about thirty or forty miles north or north-west from Ajmere, which is remarkable all over this part of India for its fine marble: the grain however would be considered as very coarse in Europe, and for statuary it would not at all answer.

Leaving Jaypoor and proceeding in a west-south-west direction, towards Ajmere, the hills, at the foot of which the former is situated, bend to the north-west; and the road passes for the first thirty miles through a sandy and uneven country, with water at no great depth from the surface. A few insulated hills appear on the right; and a range to the left is barely in view in the distance. For the remainder of the way to Kishenguhr, a distance of forty miles at the least, the country becomes clayey, with occasional gravel; the rocks, however, in some places rise to the surface, thus proving the continuity of the same substances beneath. They consist of gneiss and granite, the latter approaching to the graphic character, and apparently disposed in strata, which dip at a small angle to the horizon. Both rocks, at the surface, are in a state of decomposition, and gravel and sand of the same nature are abundant all around.

Kishenguhr is situated at the foot of a range of hills, which stretch towards the north, and probably join those of Jaypoor, which have been mentioned as deflecting to the north-west. There cannot be much doubt of their connexion beneath the surface, as their components and structure are perfectly similar: but they differ considerably in appearance, from the Jaypoor hills, assuming far more commanding and picturesque forms, and rising into lofty peaks or separating into bold masses; and this character they retain both at Ajmere and in the ranges that run to the southward. The valley through which the road to Ajmere lies, is of uneven surface, and various in its soil; and small dentated hills here and there rear themselves above its general level.

About Ajmere, the hills are much more lofty and magnificent than any our march had yet led through; and there is a wildness and disorder in their form and outline which are particularly striking. The fort of Farraguhr is built on a hill, which cannot, I think, be less than 1200 feet high: it is probably the loftiest in this part of the range. Granite, gneiss, and quartz rock were observed to prevail chiefly in this part of the country; the last differing little, if at all, from that found in the vicinity of Delhi, and like it constituting the tops of all the mountains, and assuming the same stratiform appearance. Gneiss is also found between Jaypoor and Kishenguhr, in some instances passing into fine-grained mica-slate; of which latter rock there were many varieties in colour and substance, in strata pointing generally north and south, and dipping at various angles.

In one hill, which fell more particularly under examination, this laminated mica-slate occupied about one-third of the height at the lower part on the north-east side, the strata pointing chiefly to the north, and dipping at an angle of about 20°; and above it, quartz rock occupied the remaining two-thirds, pointing towards the north-east and east, and constituting the whole of the south-west side of the hill, where no more slate appeared. It seemed, therefore, that the quartz overlaid the mica-slate from the south-westward; and the same thing was remarked in several of these western ranges.

The mica-slate and quartz rock are both plentifully veined with quartz, sometimes occurring between the laminæ, but more generally in vertical veins, running north and south. The granite in some parts of this tract is of uncommonly large grain.

There are lead mines of considerable richness in the hill of Farraguhr, worked by the Government; but the want of demand prevents them from being profitable.

It would be wrong to quit this part of the country without mentioning the Sambur salt-lake, from which annually a quantity of salt is sent, that supplies nearly the whole of Upper India. Every year, after the rains, the water becomes impregnated with so great a quantity of salt, that when the lake dries up, the salt is found crystallized in great quantity under the layer of mud, which is also deposited. Circumstances prevented me from going to visit this place, which however is not singular, for there are many lakes of less note in that part of India which yield salt of various qualities, particularly one to the westward of Jhodepoor. The soil, indeed, is in many places much impregnated with salt; and it is very rare in these parts ever to see a hollow or low place without a salt efflorescence appearing on the surface.

Our route from hence lay north-west, towards Nagore; and after a distance of twelve or fourteen miles we quitted the hills, which we observed running towards the north-east in a very distinctly marked line. From this point to Nagore our route lay entirely through a plain, diversified only by sand-hills of no importance, with clayey bottoms between them, and occasionally high and barren banks of hard clay mixed with *kunker*,—a sort of calcareous concretion, found almost all over India in such situations. The first part of this route was over a heavy yellow sand; and here water is found at moderate depths. The low clayey bottoms are fertile; being naturally moist, and generally covered with a saline efflorescence. In the higher clayey tracts, on the contrary, water is found only at very great depths, and the soil is useless, because out of the reach of irrigation: towards Nagore water is obtained at a depth of from eighty to a hundred feet. Approaching that place, the sand becomes more grey and coarse, being mingled with kunker and gravel; and throughout the whole way only one or two insulated peaks of rock are seen, which are all within thirty miles of Ajmere. Within about twelve miles of Nagore, a small hill occurs about sixty feet high, which is formed of quartz nearly of the same nature as the predominating rock of the hills we had left.

There is good reason for believing that a large portion of the country around Nagore rests on a bed of coarse red sandstone; which is found at various depths near that town, and colours part of the soil, and all the water in the tanks. All the buildings of that city are formed of this stone, from quarries dug within the walls and in the vicinity. Water is here in some places found at a small depth, and remains throughout the year in tanks dug for the purpose, not artificially made water-tight.

Nagore is built on a kunker bank, which produces nothing for more than a mile round a great part of the city. The view to the westward is as dreary as can be conceived; a succession of barren sand-hills spotted with brown and blasted-looking bushes; and towards this quarter water is more scarce, not occurring within the depth of from one hundred and fifty to two hundred feet from the surface.

The under stratum of red sandstone continues from Nagore to the southward; and as we journeyed from that place to Jhodepoor, it tinged the soil in most places, except where the hard kunker bed occurred*: it is a heavy, dull, coarse red stone, inclosing a good many crystals of quartz. About forty miles from Jhodepoor, and fifty from Nagore, this sandstone rises to the surface, and various small hills are observed on either hand, which soon unite in ranges of no great height and not very continuous. These hills also are composed of the red sandstone varying from fine- to coarse-grained, and are evidently nothing but the strata of the great bed, which rise occasionally above the general level of the country, but are quite horizontal in position. The hills never exceed from three to four hundred feet in height, and are seldom so high; their tops seem perfectly table-form, and if any where a rock or peak

* The specimens from this place were unfortunately lost.

rises above the general level, it is merely an additional stratum parallel to the rest.

The country from this point becomes undulated irregularly, the rock frequently approaching the surface; and the soil, when not a deposition of clay in the hollows, consisting generally of sand, the detritus of the hills. The scanty soil of the hills is likewise generally sand: there is also much calcareous kunker over the country; and occasional rich loamy valleys, in some of which water is found within a few feet of the surface.

An irregularly undulated tract of country, of fifteen or twenty miles in breadth, occurs between the hills just mentioned and those on which Jhodepoor is situated; and the appearance of the two ranges differs considerably. The latter hills are more rough and bare of soil, and consist of two sorts of rock; the one a freestone, sometimes resembling the red sandstone, but varying from its dull-red colour to a yellowish-grey, and from a very coarse granular to a fine-grained compact texture. This stone is easily split into slabs of any required thickness and dimensions, and thus answers many of the purposes of wood in a country where there is hardly any to be had.—The other kind of rock is clay-stone porphyry; either liver-coloured, with pale reddish spots, or of a grey colour; both varieties containing numerous small cavities like air-holes. The fracture of this rock is irregular: when fresh it is hard; but it softens, cracks, and falls into dust upon exposure to the air; and the edges and angles of the blocks falling off, leave only roundish lumps.

It was not very easy to determine the relative positions of these two kinds of rock; but, from all the circumstances, I felt disposed to conclude that the porphyry overlies the sandstone; and I never saw sandstone above it. In some of the hills however there was no sandstone, the rocks consisting entirely of this porphyry, the liver-coloured sort being uppermost; and in others nothing but sandstone could be traced. The loftiest of these hills do not appear to exceed 360 or 370 feet in height, and 200 may be more near their general elevation. They stretch a good way towards the west, but I cannot say how far. They are also seen for several miles to the northward and southward; and numerous insulated peaks and considerable masses appear fading into distance in the latter direction.

For the next thirty or thirty-five miles from Jhodepoor towards Mewar, in the direction of south-south-east, the country resembles that already described; presenting a succession of sand-hills with clay in the intervals. A few small rocky hills which rise above the surface, consist in some instances of the clay-stone porphyry, in others of the sandy stone of Jhodepoor. To the southward distant hills were seen, of greater height than those of Jhodepoor; and on the left, or north-eastward, several peaks appeared, in one of which, called Poonookur, we were informed, there are mines of lead.

About Pahlee, a town forty miles from Jhodepoor, in a south-eastern direction, we passed several small ranges and dentated peaks of a very loose reddish sandstone, inclosing in its substance large masses and grains of quartz and gravel of other sorts: the soil about them is a loose sand and gravel. Hitherto, and for some few miles further on, water is scarce, and only to be found at great depths, or in the beds of streams, which are at this season dry, though covered with a saline efflorescence. Beyond Pahlee, for the space of about forty miles, to the foot of the range already mentioned as continuous from Ajmere, and by which Marwaur is separated from Mewar, water is plenty, irrigation practicable, and the country in consequence comparatively rich and smiling. We could not discover the point where the sandstone of Marwaur ends, and the primitive rocks commence; but from the greater predominance of quartz in the hills at Pahlee, it was suspected that the change occurs in that vicinity.

This chain of mountains which we now ascended, though a very important feature in the country, does not claim any particular description: they consist exactly of the same sorts of rock, and in appearance a good deal resemble those of the same range at Ajmere. This face of the range however is more wooded, and attains a far greater height than near Ajmere; for the table-land or plateau (if so irregular and mountainous a country may be so termed) of Marwaur rises towards the south; and it is probable that the height of this part of the range is at least from 750 to 1000 feet above Mewar, and that of the mountainous peaks at least from 2000 to 2500 feet above the level of the plains of Marwaur.

It is, I presume, generally known, that the country in the central part of India, to the north of the Nurbuddah, and between the chain of mountains at present under consideration, and the valley of the Jumna and Ganges, rises —gradually from the northward towards the south, abruptly from the westward, and irregularly—that is to say, in some parts gradually, in others abruptly— from the east, so as to form a great table-land or plateau, of which the southern part (the province of Marwaur) is elevated from 1400 to 1700 feet above the valley of the Nurbuddah, and 2000 feet above the sea. It is only the western portion of this great table-land that at present claims attention. The base of this tract, to the northward, evidently consists of primitive rocks, the peaks of which appear through the general surface, forming the ranges and insulated mountains that have been described. To the southward it is composed of a bed of basalt, which forms part of the very extensive trap formation that occupies the western side of the Indian peninsula to a point nearly as far south as Goa*; but the extent of which to the eastward I have not been informed of †.

At the point we had now reached in Mewar, the country had attained a height perhaps of from 700 to 800 feet above Marwaur; and on our ascent up the Deoghur pass we found ourselves in a hilly tract, which extended all around to the north, south, and south-east: but to the north-east the country was more open, and probably lower. Our route to Odeepoor however lay entirely amongst ranges of very rugged though not lofty hills, between which the country is undulated in a very irregular manner; the rock every where coming to the surface, and rising in shapeless masses above it. Many varieties of gneiss were found here, plentifully veined with quartz, and united in the same mass with quartz abounding in mica. The strata were nearly vertical, running north and south; the laminæ were sometimes waved exceedingly; and in some instances, the softer parts having been washed away by the action of the weather, the harder portions thus waved projected, and had a very singular appearance.

The predominating rock of the hills about the Deoghur pass is quartz, which abounds every where in this part of the country; whole peaks of it appearing, pure, white and glittering like snow, and mingled with masses of a flesh colour. Limestone also occasionally occurs: and at Kankerowly, about thirty or thirty-five miles from Odeepoor, there is a lake, partly artificial and partly natural, the magnificent dams of which are entirely built of a species of marble, found close in the vicinity, at a place called Rajnugur.

About Odeepoor itself, the summits of the hills are composed of granite and quartz rock: and about their foot schistus of various sorts is found. A compound of quartz and mica is among these strata; the course of which is invariably from north to south, the angle of deviation from the vertical plane not exceeding five or ten degrees to the west or east; and in every instance they are plentifully pervaded by veins of quartz, in the same direction with the strata.

* Trap rocks have been traced to the south as far as Malwan, fifty miles north of Goa; and their junction with granite probably occurs near the former place.

† It would appear that the trap formation extends to the eastward at least as far as the vicinity of Jubulpoor and Mundlah, near the head of the Nurbuddah.—There are in the collection of the Geological Society specimens, presented by Mr. Jack, from the banks of the river in that vicinity, consisting of chalcedony, quartz, and green earth, in nodules which appear to have been derived from the amygdaloid of the trap formation.—Ed.

Rocks were likewise met with here as at Ajmere, that seemed to defy classification; masses of quartz, schist, and granite, huddled together in pieces of all sizes, as if the whole had been overthrown and heaped into one mass of confusion. Above all this, reddish felspar and quartz rock are always found in strata, dipping at various angles from thirty-five to eighty degrees to the horizon.

Besides these predominating rocks, it is probable that green jasper and porphyry occur in the vicinity of Odeepoor, as articles and ornaments of these substances are seen in the city. A fine black stone resembling marble is also much in use, which is susceptible of a considerable degree of polish, and is cut into beautiful sculptures and ornaments: it is probably only a variety of the dark slate of the country. Marble, both white and grey, is also much employed, but it all comes from Rajnughur, near Kankerowlee.

From Odeepoor our route lay towards Neemuck. The distance from the former place to the eastern boundary of the hills among which it is situated, is about thirteen miles; and from hence a comparatively plain and open country commences, with but one or two hills rising above its level, and these were near the range we had passed. The rock was of precisely the same red granite that we saw at Odeepoor; and the connexion seems to be preserved as far as a range of low hills about fifty to sixty miles east of that place, which consist chiefly of quartz and granite; but after that point we saw no more of the primitive rocks.

Just below the range last mentioned, is found a compact limestone of a greenish-grey colour and splintery fracture, effervescing strongly with acids: and this rock seems to form the basis of a considerable tract of country. The strata, which are very distinct, are horizontal, or dip to the north-east or south-west at an angle not greater than from ten to fifteen degrees. The soil that lies on this rock is a loose black mould, which in dry weather gapes and cracks in all directions to a considerable depth.

In the vicinity were low hills, of a very different character from those we had left; their tops were level and compressed; and they looked more like mounds of artificial construction than natural hills. These were in fact the commencement of the trap formation of Malwa and the Deccan. They appeared to consist of yellow or reddish earth, of an ochry nature, with gravel and rounded stones. In the plain, both among this gravel and the black mould, numbers of agate-like pebbles were found of a semi-transparent horny or milky colour; and a few miles onwards, within four or five miles of Neemuck cantonment, the low round hills were covered with rounded stones in great profusion, and of all sizes, consisting of the black basalt, that forms the basis of the whole country to the Nurbuddah, and far beyond it to the southward*.

From this point to Jam-ghat, on the extremity of the table-land of Malwa, and on the descent to the Nurbuddah, the geological nature of the country suffers little or no alteration in appearance or in reality. Extensive gentle undulations, of no considerable height, are divided from each other by small water-courses, which for most part of the year retain a certain quantity of running water. These heights are sometimes covered with the deep black mould universal in Malwa and several of the elevated countries that occupy this plateau: sometimes we find a hard dark and stony soil, denoting that at no great depth below the rock the same black basalt is to be found. Around Neemuck, and for some distance to the south and eastward, red ironstone is found, occupying some of the low rounded hills that occasionally occur, as well as the extensive undulating downs which form the country. Compact limestone, containing sparry iron ore, is used in building; and the greenish-grey limestone, already mentioned, is found in several places in the vicinity, and is used in various ways.

The same description applies to the country south from Neemuck to Pertaubgurh, and from thence to Deola, a fort on the brow of the hills overlooking the jungle that stretches towards Goojerat. The hills are far from lofty, and the fall to the westward is either uniform, or broken into various descents by a gradation of hills.

We then proceeded eastward, by Mundussor, to the banks of the Chumbul at Aorah-ghat, through a country precisely similar; small hills of black basalt, with their level stratiform tops, occasionally rising out of the ground. The river runs in a bed of black basalt, about sixty feet deep from the surrounding country. The surface of this rock, when exposed, appears to be split into hexagonal pieces approaching the columnar form; but no columns are to be found. The whole rock is much tinged with iron. Agate-like pebbles, and other forms of quartz, are scattered thickly all about; and we now began to find geodes of quartz, which afterwards occurred in great abundance.

The banks of all the considerable streams in this part of the country were composed of a very fine light-coloured grey clay, in great depth, which rested upon the basalt, instead of the black mould or red gravel constituting the soil of the country already described.

About four miles to the eastward of Aorah-ghat there is a range of hills,

* The specimen of this rock, sent with this paper, was obtained from a well sunk about twenty-five feet below the surface, in which there had been eighteen feet of this stone already blasted through.

not many miles in extent, and not more than from 150 to 200 feet high, principally composed of a cellular clayey brown iron ore; which varies much in hardness, inclosing masses both of soft unchanged clay, and hard nodules and veins of a highly metallic character. To the southward of this place, the strong tinge indicating the presence of much iron is no longer observed; and the country is exactly like what has already been described, the whole way to the cantonment of Mow, only sixteen miles from Jam-ghat. There are in this tract several basins, as it were, of a fine grey clay: and in one of the most extensive of these is situated the city of Oogen, of which the fable is told, that it was overwhelmed by a shower of cold earth. But there is not in the place itself, or in the vicinity, any reason to suspect the former occurrence of any convulsion of nature from which the fable may be supposed to have originated; every thing, on the contrary, indicating that the old city has merely experienced that gradual decay which has swept from the face of the land so many Indian cities of celebrity and grandeur, the vestiges of which are now seen only in heaps of rubbish similar to those found in old Oogen.

It has been already stated that the table-land of Malwa sinks abruptly to the bed of the Nurbuddah,—or rather to the valley of Nemaur, in which that river runs. This range of ghats forms the southern boundary, if not the whole mass of what are known by the name of the Vindhya mountains. Their peaks rise but little above the level of Malwa; but there is a chain or succession of such peaks along that part of the mountains which came under our view in the course of our journey; and the abrupt face of this mountainous barrier exhibits perhaps as perfect and interesting a specimen of the formation of the country as can any where be seen. The upper part, for several hundred feet, is almost perpendicular; and even below this, though the slope is more considerable, yet the angle of elevation is very great. On the face of the hill thus exposed, to the depth of full 1500 feet, are seen numerous strata, strictly parallel, and running in a horizontal direction, which appear to consist alternately of rock and soil, or at least of harder and softer rock, and on inspection prove to be the common black basalt and amygdaloid. There are fifteen or sixteen such strata distinctly to be reckoned. This amygdaloid is plentifully studded with zeolite, in masses of various shapes, and generally coated with green earth, which is sometimes of considerable thickness, at others merely superficial. The amygdaloid itself is of various degrees of hardness; from that of stone fit for building, to a soft, decomposing, almost earthy mass. It appears as if the rock cracked by exposure to the air, that the corners then commenced mouldering off, and were succeeded by flakes, scaling off like those of an onion, and leaving the centre as if a kernel. The more solid rock is universally the dark-coloured basalt, which sometimes assumes the hexagonal appearance remarked in the bed of the Chumbul and of several other rivers; and now and then approaches nearly to the columnar form. Throughout this range of hills, and generally among the whole of the trap formation in these parts, fragments of quartz and zeolite of various shapes are found scattered in great abundance. Quartz is found also in veins in the basalt, as well as in geodes, in which calcareous spar very often fills up the interstices of the quartz crystals.

The basalt in these countries rarely assumes the columnar form; but at Mundlisoor, on the banks of the Nurbuddah, a small hill exhibits on its crest a series of basaltic pillars, chiefly hexagonal: they are about a foot in diameter, and from two to four feet high; and a fine tessellated pavement is formed by their tops, which are on a level with part of the ground. A dyke of very compact stone, like Lydian stone, crosses the basalt on the river bank, near the same place, projecting from its surface in a remarkable manner.

The valley of Nemaur, on both sides of the Nurbuddah, exhibits the same geological phænomena as Malwa: we however passed along the top of the Vindhya range, reascending the ghats, and observing formations perfectly similar to those at Jam, at Mundoo (the ruins of an old town on the verge of the descent), at Dhar, and some other places in the neighbourhood, as well as at Oogen. Reddish limestone, of a beautiful and remarkable character*, is here used in ornamental buildings; I could not learn whence it came, but from the quantity made use of, it cannot be far from Mundoo. There was likewise in use a species of black marble, which probably is also found in the neighbourhood.

Passing on to the westward, we descended the mountains at Tanda-ghat, between Bhopawar and Baug. The ghat itself consists of the same rocks as the other parts of the hills,—basalt and amygdaloid, with zeolite and quartz in various shapes; but at the foot of the hill, and among the lower rocky rising grounds, we found a rock consisting of quartz and felspar, apparently belonging to the granitic formation: it occurred in a hollow, and was lost in the rising of the next hill, not extending to any considerable distance. A little further on clay-slate resembling greywacke slate was found, in vertical strata (as in the Ferimar hills), running about north-west and south-east; and gneiss occurred several times in large masses: quartz was more abundant; and we

* This stone appears to consist of an intimate mixture of yellowish-grey splintery limestone, similar to that of Neemuck, with limestone of a reddish hue. The specimen contains fragments of coral, and small specks of quartz.—Ed.

passed some remarkable rocks in beds, consisting of gravel, concreted by a cement with the nature of which I was not acquainted.

A little further on we came among sandstone hills, brown, red and grey, in horizontal strata. The fort and town of Baug are built on a hill of this description; and our route continued among sandstone of the same nature for six or eight miles, the heights differing little in appearance from the low trap hills of the other parts of the country. The strata were horizontal; and the whole being covered with thin short jungle, the change would not be readily remarked, were not the rock of the whole country, which rises to the surface in our very path, composed of the same sandstone. It was difficult to preserve specimens of this rock, as they soon mouldered away: it is generally very crumbling, and of various colours, from dark brown and heavy red, to yellow and dead white: and in some portions there is a great admixture of clay. The colours were in strata, and all horizontal. In several of the hills composed of this stone, we remarked that the sandstone was overlaid by strata of compact yellowish-grey limestone in beds varying in thickness, but apparently from ten to twelve feet thick, above which there was a thin coat of soil. This limestone evidently much resembles that first remarked on entering the trap formation near Neemuck.

Descending further towards the Nurbuddah, into the valley of Nemaur (or rather, I believe, the district of Ally Mohun), we again found the black basalt, which in the bed of one stream approached the columnar form. The whole bed of the Nurbuddah is here worn in a basaltic rock; and at the period we crossed it, having little water, it was sunk from sixty to one hundred feet below the level of the surrounding country. Above the basalt, close to, and for a few miles distant on each side the banks, the light-coloured fine clay, before alluded to, is found to considerable depth.

Some few miles below the point at which we crossed the Nurbuddah, the Sautpoora range of mountains, which intervene between Nemaur and Candeish, approach close to the river's bank, and are met by the Vindhya range on the other side, so that the river forces its way through a succession of rapids, which obstruct the navigation for several miles. The Sautpoora differ extremely in appearance from the Vindhya mountains, being bold and romantic in the outlines, rising into lofty peaks, and swelling into shapes that would induce the beholder from a distance to consider them as primitive: he is, however, soon undeceived, for on approach the same structure in horizontal strata becomes apparent; and notwithstanding the diversity of their outline, and more picturesque appearance, the description given of the Vindhya range, and the catalogue of the substances there found, will also apply to the Sautpoorah mountains. The highest peak of the latter is about 2500 feet above the sea, and consists of amygdaloid, green stone,—which seems to form more than one-half of the entire hill,—and at the top of basalt.

From this place to our entrance into Candeish, by the Sindwah-ghat, there seems nothing to remark: the route lay through a poor jungle, clothing scantily a succession of low barren hills, the dark rock every where starting through the surface.

Candeish is a singularly situated country; a low district surrounded on every side by higher lands; so that from every direction there is a descent into it: but this descent has probably been overrated, as the great though gradual ascent from other quarters to the passes which lead into Candeish, has not been taken into due consideration.

The soil of Candeish differs from that of Nemaur and Malwa; a fine rich chocolate-coloured mould taking the place of the black, deep, gaping soil of those places: there is here, it is true, much sand, and much hard unkindly soil of gravel and kunker; but many of the chief districts might be again rendered, as they once were, extremely fruitful.

The heights, known as the Inyadree hills, which separate Candeish from the district called the Gungleteree, present a very extraordinary aspect, and afford a singular specimen of the fantastic shapes which rocks of the trap formation assume. They rise to a certain height in a continuous range, marked at intervals by the strata of which they are composed; a distinct horizontal line runs along the whole; and the various masses that form the individual hills rising above this line, as from a base, at some distance from each other, attain the height of a few hundred feet more, traversed by other horizontal lines at still more elevated points. Some of the heights terminate, after one or more such stages, in a level table-land; others rise still higher, but on a reduced scale, so as to leave unoccupied a part of the subjacent table: and this succession is several times repeated, till the mountain ends in an insulated columnar mass. The outline, Plate XXIV. fig. 2. will perhaps give a clearer idea of this structure than any description.

Our route lay through the ghats near Candeish, Chandoor, and the district of Gungleteree, to Nassuck, and thence down the ghats, and through the northern Concan to Bombay. It exhibited only a repetition of the same mineral and geological phenomena of which a description has been attempted: but the rapidity with which we passed did not allow of any minute or laborious investigation.

The singular forms of the hills which bound the table-lands of India at this point, and are known by the name of *The Ghats*, have been the theme of every traveller: but though ever varying, they may generally be referred to the same principles of structure that have been mentioned in treating of the Inyadree hills; the heights being all most distinctly stratified horizontally, with successive ranges or portions of strata arising, in a diminishing series, to form their summits.

Remarks on the preceding Paper, by the Secretaries.

The distance from Delhi to Bombay, in a direct line, is about 700 English miles; but Mr. Fraser's route, including his deviations from the immediate line of communication, very considerably exceeds that distance. For the reasons mentioned in the beginning of the paper, a small number only of the specimens which the author collected has reached the Society: but these are nevertheless sufficient, in combination with his narrative, to point out some interesting features of geological resemblance between the districts described and other parts of the world.

The specimens which Mr. Fraser's collection includes belong,—1. to the primary formations;—2. to the secondary rocks;—3. to rocks of the trap formation;—all of them according in composition and character with rocks of the same classes from other countries.

1.—The extent of the primary tract in the central part of India, seems to be very considerable. It appears from the present memoir to occupy the greater part of the country between Delhi and Neymuck; and to occur again in the neighbourhood of Baug, and near the banks of the Nurbuddah, where gneiss and granite are visible under beds of sandstone, limestone, and trap. Primary rocks are found also, much further to the south, on the coast near Goa; not far from whence, to judge from other specimens in the collection of the Geological Society, they join the trap formation.

The place of the quartz-rock is pointed out by the author as being superior to the granite, gneiss, and mica slate; and it appears that the hills composed of that substance agree with those of similar composition in Europe, in presenting detached peaks and conical summits; a fact exemplified remarkably in the island of Skye and in the Paps of Jura, among the western islands of Scotland*, and in the sugar-loaf mountains of the county of Wicklow in Ireland †.

2.—Among the substances of more recent formation than the primary rocks, are greywacke slate, sandstone, and limestone.

* Geological Transactions, Vol. ii. Plate 32. p. 450.

† Ibid. Vol. i. p. 271., and Vol. v. p. 188.

The appearances of the tract around Jhodepoor, on the west of the primary mountains, as described by Mr. Fraser, bear a very distinct resemblance to those of the new red sandstone, or red marl formation of England; and the specimens of reddish sandstone from that part of India precisely resemble those of the red marl of Somersetshire, Devonshire, and other counties in which that formation exists. The occurrence of claystone porphyry in connexion with this sandstone, is a further point of resemblance; the specimen of the former substance from the Jhodepoor hills, agreeing exactly with the porphyritic masses which are found in the red marl of Somerset and Devon. The nature of the connexion between these rocks in India is, however, deserving of further inquiry; and in England it is still involved in some obscurity.

The description and specimens of the sandstone which occurs at Baug and in its vicinity, at a considerable distance from the districts above mentioned, agree with those of the sandstone from the neighbourhood of Jhodepoor, and of the English red marl.

From the statement of Major Rennell, that "the tract between the Indus and the Chelum is wonderfully productive of salt mines, affording masses of salt hard enough to be formed into vessels*," Dr. Kidd has been led to suppose that the red marl formation probably abounds about the stream of the Indus. The facts mentioned by Mr. Fraser add strength to this conjecture; and it is highly probable that the vast sandy deserts on the west of India, throughout which salt lakes occur, belong to the same formation;—which is known to occupy extensive tracts (and in many instances to assume the character of sandy deserts) in Russia † and various parts of the continent of Europe, Africa ‡, and North America.

The relations of the secondary limestones, mentioned by Mr. Fraser, are well deserving the investigation of future inquirers. In the vicinity of Baug, the order of the rocks appears to be, granite, clay slate (or greywacke slate?) in strata nearly vertical; red sandstone in horizontal strata; and above these compact yellowish-grey limestone, resembling that which is described as occupying a considerable tract of country in the vicinity of Neemuck, about 140 miles to the north of Baug.

3.—The position and appearances of the trap rocks described by Mr. Fraser, are no less in accordance with those of similar composition in other countries. The specimens are almost identical with the basalts and amygdaloids of

* Rennell's Hindostan, p. 69; quoted in Kidd's Geological Essay, p. 115.

† See Mr. Strangways' paper on the Geology of Russia, in the preceding part of this volume.

‡ See the Rev. W. Buckland's remarks on specimens from the interior of Africa.—Lyon's Travels in Africa; Appendix.

Europe;—and the sketch of the heights, Plate XXIV. fig. 2, might have been taken to represent a portion of the coast of Antrim in Ireland. These heights in fact consist of successive alternations of basalt and amygdaloid; and the effects of decay, upon a series of beds which differ so considerably in firmness and durability, have produced, in India, as elsewhere, those external features, from whence, it is well known, the term *Trap* was originally applied to rocks of this description *.

The map, Plate XXIV. exhibits in one view the principal parts of India which have formed the subjects of communications hitherto presented to the Geological Society: and it must be very gratifying to perceive, notwithstanding the small number of the persons to whom the Society is indebted for these contributions, that a body of information has already been obtained sufficient to point out some of the leading geological features of that vast country, and to suggest to future inquirers several interesting subjects for more detailed research. The general resemblance of the fossils from the north-east of Bengal to those of the formations above the chalk in England;—the geological characters and organized contents of the great flat country on the east of central India, along the Ganges and its tributary streams;—the relations of the lime-stones of Silhet, Laour, and Robagiri, and of Neemuch and Baug already alluded to;—and the coal formation on the banks of the Tístá and Súbúk rivers, are all of this description; while the specimens from the Sutluj, where that river traverses the Himálaya mountains, establish the identity of the rocks composing that stupendous chain, with those of the primary ranges in all other parts of the world hitherto examined.

The map is partially coloured, for the purpose of designating some of the tracts referred to and described in the present Volume, and in the fifth Volume of the Transactions of the Society: which contain also,—besides the papers relating to the portion of India included in the map,—a memoir of Dr. Davy on the Island of Ceylon; of Mr. B. Babington, on the route from Tellicherry to Madras; and a notice by Mr. Jack, on the Islands of Penang and Singapore.—These valuable contributions from the most important of the British colonies, are, it is to be hoped, an earnest of the geological information that may be expected by this Society from the continued activity of its members, and of other British subjects, who are engaged in the service of their country in distant quarters of the globe.

* *Trap* in the Dutch language (Swedish *Trappa*—German *Trappe*) signifies *stairs,—a staircase.* The word *Trap* is applied in a similar sense in some of the English coal-districts, to *Faults*, where portions of the strata are elevated or depressed.

XIII.—*Notices and Extracts from the Minute-Book of the Geological Society.*

1. *A Notice on Fossil Plants found at the Col de Balme, near Chamouny in Savoy.—By* H. T. De la Beche, Esq. F.R.S. &c. [Read Nov. 3, 1820.]

THE Col de Balme, which closes the valley of Chamouny to the north-east, and separates Savoy from Switzerland, has long been known for the superb view which it commands of the valley of Chamouny, with the Mont Blanc range in one direction, and the mountains of the Valais in the other. The iron cross on the highest part of the Col, or passage, is, according to M. De Saussure, 7086 French feet (7558$\frac{6}{15}$ English feet) above the level of the sea.

The Col is composed of beds of clay slate, of limestone, and of a few thin beds of sandstone. The rocks of the Col de Balme have been called primitive by M. Ebel, in his Bau der Erde in dem Alpen-Gebirge; but were with more justice named secondary by M. De Saussure *. The beds which compose them seem to be a continuation of the limestones which are remarked in patches in the valley of Chamouny; and which probably once occupied the whole length of the valley.

While crossing the Col de Balme, in the autumn of 1819, I picked up two portions of the thin beds of sandstone above mentioned, which I found to contain vegetable impressions, precisely similar to what have been termed coal-plants, because they are usually found in coal formations. But I tried in vain to find these fossil plants in situ; many parts of the Col being too precipitous to allow of my approaching them.

I was, however, fortunate enough, when at Chamouny again, in the spring of 1820, to purchase two or three specimens of fossil plants, which had been found at Col de Balme. One of these was remarkable, as the impressions of

* Voyages dans les Alpes, Chap. xxii.

the coal plants were on clay slate; and all the impressions, which were numerous, were covered by beautiful white talc in very thin laminæ.

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2. *Notice accompanying Specimens of Lead Ore, found in Toadstone, from near Matlock, Derbyshire. By* Charles Stokes, Esq. F.R.S. &c. [Read Nov. 3, 1820.]

The specimens of Galena from the neighbourhood of Matlock, which accompany this notice, are from veins which have been worked with profit in the toadstone as well as in the limestone. One of them is from the Side mine under the High Tor, the other from the Seven Rakes mine, on the right bank of the river not far from the bridge.

The circumstance of the veins of lead being continued through the toadstone, although formerly denied, has been ascertained of late years in many instances; but it has rarely occurred that they have been worked in that rock. This has arisen from the belief, commonly entertained and asserted by most of the miners of Derbyshire, that the veins are productive only in the limestone; though it may perhaps appear on further examination, that this opinion has been too hastily adopted; and the circumstances of the working of the toadstone in the Seven Rakes mine, show that this is probable, and that some change has taken place in the opinions of the miners themselves on the subject.

This vein was formerly worked, to the depth of about thirty fathoms, in the first limestone; when, on coming to the toadstone, the work was abandoned, as it was supposed that the vein was cut off by that bed. Some years afterwards a level was driven into the hills, from near the river, to carry off the water, and the vein was worked in the second limestone, underneath the toadstone, which was left untouched. The vein was again abandoned when the workings were carried to a depth at which they could no longer be kept clear from water: but about a year ago five working miners took a set of the ground, in order to work the vein in the intermediate bed of toadstone which had been left, and the undertaking has proved profitable.

Mr. Tissington, the owner of the Side mine, who communicated to me these circumstances, informs me that the veins, in all the instances he is acquainted with, are continued through the toadstone, although they frequently do not bear well in that rock; and also that a vein frequently changes its degree of inclination in passing through it. And sometimes, after such a change in inclination, the vein again returns at an abrupt angle, like a V placed horizontally.

3. *Notice respecting a Copper Mine at Cally in Kircudbrightshire. By* John Taylor, Esq. M.G.S. [Read December 15, 1820.]

The main land of Scotland has not, I believe, heretofore produced any quantity of copper ores worth the notice of the miner; though that metal was obtained a few years since from a vein in a bed of limestone in one of the Shetland Islands, where a steam engine was erected; and the produce for a time was not inconsiderable.

The mine, I am about to describe, is near a small town in Kircudbrightshire called Gatehouse in Fleet, which is on the mail road from Dumfries to Portpatrick. It is on the estate of Mr. Murray, and is situated on a hill rising above the grounds that surround his house at Cally, and slope southward towards the river Fleet and the Solway Frith.

The rocks of this neighbourhood are Killas, very similar in all respects to that of Cornwall: this resemblance struck me much on the road west from Gatehouse as far as Portpatrick, and particularly in passing between Creetown and Glenluce, where the similarity in the general features of the two countries is very striking. It does not appear, however, that there have been many veins discovered in this district, though I should think it probable that they exist. Some veins however, producing lead, have been worked near Gatehouse for several years, but not with any vigour, or in such a manner as to prove much respecting them. Copper was, until very lately, totally unknown there, and was now found by accident, on the spot above described, by a labourer employed with others in cutting a drain in a swampy piece of ground near the top of the hill. Specimens of the ore were sent to different places for the purpose of ascertaining what it was,—among others to Edinburgh and Liverpool; and from the latter place to Anglesea, where it came under the notice of my friend Capt. Treweek, the manager of the Mona mine, who some time after visited the spot, and formed a company for the purpose of raising it.

The mine was commenced by sinking a shaft at the place where the ore was first discovered, and this was continued to about eight fathoms in depth; ore being produced from the shaft as it went down, as also in the vein or lode to the east and west of the shaft. The vein was not very regular in these first trials, being disordered and split into branches; which, though frequently rich to the width of six or eight inches of solid ore, were changeable and uncertain. They had been traced in a direction from east to west for nearly a hundred fathoms; and their branches appeared to converge towards each other in descending, so that it is probable that at greater depths they may be united to form a single vein.

When I visited this mine, at the end of August 1820, water was so abundant in the vein, that it had been found necessary to commence an adit for the purpose of taking it off. There had then been shipped for Swansea about forty tons of copper ore, estimated to be worth nearly 15*l.* per ton; and there were at the time above mentioned about twenty or thirty tons ready to follow that which had been sent away. This produce is rather remarkable in proportion to the extent and cost of the work; it being unusual to find copper in abundance so near the surface; and when it occurs in this manner, it is not deemed by miners a good omen of its continuance in depth;—but this opinion is not much to be relied on, as there are many mines which have proved very productive where the ore has been so situated. The ores were rich, and of a mixed character, containing the yellow and coated varieties of copper ore, with some green carbonate.

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4. *Extract from a Letter from Mr.* William Jack *to* H. T. Colebrooke, Esq. V.P.G.S. &c. *containing a Notice respecting the Rocks of the Islands of Penang and Singapore.* [Read December 15, 1820.]

You will receive with this letter specimens of the rocks which occur in the islands of Penang and Singapore, at the western entrance of the straits of Malacca. The island of Penang is entirely composed of granite, varying considerably in the fineness of the grain, and sometimes containing hornblende, or becoming what would be called syenitic. I have sent one specimen which contains very large and perfect crystals of hornblende and felspar.

At Singapore the rocks are secondary. The principal one is a red sandstone, whose strata have a very considerable dip to the south or south-eastward. This changes, in some parts, to a breccia or conglomerate, containing large fragments and crystals of quartz. Strata of a slaty clay, which becomes soft by exposure to the weather, often accompany the sandstone; and an alluvial bed of clay occurs in the channel of the river adjoining the town. A small hill in the same neighbourhood is composed of an argillaceous ironstone.

These appear to be the prevailing minerals along this side of the Malay peninsula, and throughout the islands which lie at its southern extremity. The central ridge is probably primitive. The sandstone seems to be the chief secondary rock; and the ironstone, I have mentioned, occurs abundantly along the whole line of coast.

These last two seem to be connected with the alluvial deposits of tin, which are here so abundant, and are worked to such advantage. The principal mines on the peninsula, are at Salengore and Pera, where they appear to be similar in position, and to be worked in the same manner with those of Banca. The tin is found in horizontal beds alternating with clay strata, and is so pure as to require only to be washed and fused. The position and origin of this tin is a subject of curious inquiry.

I have as yet been too short a time at Sumatra to say much of it, but it promises to afford a most interesting field of research. On it the primitive and volcanic ranges appear to meet; the former descending in a south-eastern direction from the Himálayan range, through the Malay peninsula and the parallel island of Sumatra, till it meets the volcanic series, which runs from thence nearly east, through Java, and the chain of islands that lie off the eastern extremity of that island.

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5. *Notice on a recent Deposit of Compact Limestone. By* Charles Stokes, Esq. F.R. and L.S. M.G.S. &c. [Read December 15, 1820.]

The fact which I am about to describe, appears to me to throw some light upon the formation of some of the compact beds of limestone, in which, as in the mountain limestone, fossil shells and corals are so completely preserved as to retain their most minute parts in a perfect state.

A short time since a mass of fragments of recent corals and shells, which I believe to be from the Mediterranean, was brought to me on account of a number of terebratulæ being fixed upon it. As they adhered chiefly to one surface of the mass, I broke it to reduce its size; but was much surprised on doing so to find irregularly mixed with the mass a considerable quantity of limestone, which had all the appearance and the fracture of a mountain limestone, or the more compact kinds of white lias. And on more minute examination, I was convinced that this limestone was a quite recent deposit among the branches and fragments of the coral.

The chief part of the mass consists of pieces of the red coral of the Mediterranean, *Corallium rubrum* of Lamarck (*Isis nobilis,* Linn.; *Gorgonia pretiosa,* Solander and Ellis), many of which I found running completely through the limestone, and retaining still their well known red colour. As this coral could not penetrate any solid substance, much less a compact rock,—for it can increase in size only by the uninterrupted growth of the small animals which secrete the matter of it,—it necessarily follows that the limestone must have been deposited around the coral.

Some of the fractures of the limestone show that it has enveloped other corals (one of which retains all its beautiful markings and prominences) as well as some of the terebratulæ, which are not placed in hollows of the rock, as is the case with the lithophagous shells, but are so completely invested, that it would be impossible for the animal to exist within such an inclosure.

Of the circumstances under which this deposit has been formed I am not able to give any account; but they were doubtless analogous to those under which the rock was formed in which the human skeleton was found at Guadaloupe. That rock was composed entirely of fragments of corals and shells, held together by a calcareous cement; but, in the present instance, the cementing deposit is itself in such abundance as to assume the character of a compact rock.

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6. *Notice accompanying Specimens from the Neighbourhood of the Gáró Village of Robagiri: extracted from a Letter from* D. Scott, Esq. *of Bengal,* M.G.S. *to* H. T. Colebrooke, Esq. V.P.G.S. [Read March 2, 1821.]

THE country between Harigong and Robagiri has been already generally described in Mr. Colebrooke's paper on the North-east of Bengal, in the present Volume. The village bearing the latter name is situated about twenty-five miles east from the Brahm-putra in Purgunnah Caribari.

" In some places, on the mountain north of Robagiri (which is mentioned, p. 136, as being more than 4000 feet in height), ridges of gneiss appear, particularly at the top, in an almost vertical position. At Robagiri itself, above the white clay mentioned by Mr. Colebrooke (p.136), a stratum of limestone abounding in nummulites appears in the bed of the river. The position is slightly inclined from the horizontal; its thickness about two feet. It is crossed by vertical fissures, dividing it into oblong rectangular blocks; and rests upon, and is surmounted by, beds of clay, which also itself contains nummulites of similar character to those in the limestone, but less numerous, and of smaller size. In some places this limestone appears to contain bones*. On the opposite side of the river perpendicular cliffs of slate-clay, horizontally disposed, rise to a considerable height. Close to a chalybeate spring, issuing from the foot of these cliffs, is found bituminous shale, having the appearance of wood; and near to it is bituminous wood. The sandstone, clay, &c. of the lower hills

* In one of the specimens there are two small vertebræ of some fish, exactly similar to those found in a clay from the same place :—This clay contains also an ostrea and a ribbed pecten.

appear, in general, to be disposed nearly in a horizontal position, where their structure is at all visible; but being covered with soil and vegetation, this is seldom the case. The stratum of limestone with nummulites is at the bottom of a hill, which seems to rest upon it."

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7. *Notice on Fuller's-earth found in Chalk in Sussex. By* F. Sargent, Esq. [Read June 1, 1821.]

On the northern side of the South Downs, near the village of Bepton, in the neighbourhood of Midhurst, there occur two strata of fuller's-earth, which intersect the upper chalk formation at a little distance from the summit of the hill, in a nearly horizontal position, dipping a very little to the west. There lies about one foot of chalk above them, and they are about three or four inches in thickness. This substance bears all the characteristic marks of fuller's-earth, being unctuous, transparent at the edges, and falling into a powder when thrown into water. Underneath these strata, and towards the middle of the hill, lies a stratum of chalk-marl, in a similar direction and of equal thickness, which appears to contain the substance above mentioned.

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8. *Notice on the Black Oxide of Manganese of Warwickshire. By* S. Parkes, Esq. F.L.S. M.G.S. &c. [Read June 15, 1821.]

I am induced to send the specimens which accompany this notice to the Society, because they are of a very different character from any which I have seen from Cornwall, Devonshire, or Scotland. I find also, by experiment, that this manganese contains more oxygen than that which is usually procured from those districts.

This, which I now send, was found at a place called Hartshill, near the towns of Atherstone and Nuneaton, in the county of Warwick. The soil in the neighbourhood is chiefly a red clay, and the manganese usually occurs in detached pieces, distributed through the clay, weighing from one pound to fifty or sixty pounds each, and from one foot to six or eight feet below the surface of the ground.

It was in the year 1818 that I first heard of the oxide of manganese having been found in Warwickshire: and in the latter part of that year I made a journey into that county for the purpose of searching out the mine, and learn the following particulars:—

That the first manganese which was obtained in Warwickshire, was found at Hartshill, on the estate of T. L. Ludford, Esq. of Ainsley Hall, about two miles from Atherstone. A poor man, of the name of Hankinson, who possesses a small field adjoining to Mr. Ludford's estate, has since found manganese in his land, and has raised a considerable quantity. A man of the name of Davis has also raised some, and sold it at a good price to the bleachers in Lancashire.

Any member of this Society, who may be desirous of visiting the place where this mineral occurs, may receive further information by applying to Dr. Power, of Atherstone, who has taken a great deal of interest in the discovery.

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9. *On the Gypsum of Monte Seano. Translated from a Letter from* M. Scipio Breislak, *Inspector of the Nitre Works, &c. at Milan, to* G. B. Greenough, Esq. M.G.S. &c. [Read November 2, 1821.]

To comply with your wishes, I have undertaken an excursion of fifty Italian miles to the gypsum quarry of Monte Seano, where the fossil plants are found, respecting which I give you the following minutes.

The hills on the right of the Po, which are called Stradella, connect the hills of the Placentine on the east, with those of Tortona and of Novi on the west, ending to the north in the valley of the Po, and to the south at the Appenines of Liguria. A considerable formation of gypsum is observable on all the hills of the Stradella; and the most interesting part of it is doubtless that at Monte Seano. It is necessary to bear in mind, that on all the hills a great quantity of remains of marine bodies are met with. (See the Fossil Conchology of the Sub-Appenines, by Brocchi.)

The gypseous deposit of Monte Seano is covered by a bed of yellowish arenaceous marl, which effervesces strongly in acids. In this marl bed, of four or five feet (Parisian measure), are found:—

1. Many rounded masses of the same marl.

2. Some large irregular crystals, which have the rhomboidal form of gypsum.

3. A thin bed of whitish compact gypsum, of a scaly foliated fracture.

Under the bed of marl Gypsum occurs, in horizontal beds from two or three inches to three or four feet in thickness. These beds of gypsum are often interrupted by thin layers of grey schistose marl, containing sometimes small veins of fibrous and of granular gypsum.

The gypsum of this quarry is penetrated with a bituminous matter, the odour of which is rendered perceptible by percussion or friction: it is rather compact; its texture is most frequently granular, sometimes scaly foliated; and sometimes it is found in small thin fibres. Its general colour is a light grey, but also sometimes dark, approaching even to black. The rock on which this gypsum rests is not ascertained, and veins of marl are observed in some instances to intersect it.

The phenomenon which renders this quarry very interesting is the great quantity of vegetables which it contains. Every where stems and leaves of plants are met with; but it is very difficult to obtain such characteristic specimens as to determine their genera. The coaly impressions of the leaves are generally broken. In a fine slab in my possession, six feet eight inches high, three feet wide, and four inches thick, impressions of the leaves are seen of a darker colour than usual: the contours of some are very evident, and one may see the fibres of the leaves. The stalks which are disseminated very irregularly, are compressed, carbonaceous, and can be detached in some places. Professor Moretti discovered amongst these plants the leaves of the Salix capræa, the Viscum album, and the Acer platanöides,—plants which grow at present in the neighbourhood of the quarry.

The occurrence of the remains of vegetables inclosed in gypsum is not uncommon in other places.—In the Montmartre gypsum, trunks of the palm-tree have been found; but I am not aware that impressions of leaves and stems have been seen in such quantity as at Monte Seano.

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10. *Notice on the Rocks of Attica. By* Joseph Woods, Esq. F.L.S. M.G.S. &c. [Read March 15, 1822.]

Attica is a promontory, bounded on two sides by the sea, and divided from the remainder of the Grecian continent by a range of mountains, the highest point of which, the ancient Parnes, now Nozea, may be about 4000 feet above the sea.

Within the triangular space thus bounded, are also numerous mountains, very irregularly disposed. The greatest heights are those of Pentelicus, about 3500 feet, and Hymettus, about 2500 feet*; and between the moun-

* The heights here stated are given upon estimations derived principally from the duration of the snow upon the mountains.

tainous groups are three or four spaces comparatively plain, the most remarkable being that of Athens, which has a general direction from north-east to south-west. This plain is bounded on the east, north-east, and north, by the mountains Hymettus, Pentelicus, and Parnes; and it is separated on the north-west, from the plain of Eleusis, by a broken chain of hills, which is continued from Parnes to the sea, and includes the ancient Ægialus and Corydalus, between which is placed the convent of Daphne.

The plain of Athens is subdivided by a series of hills, on part of which the city is placed, including the connected group of the Museum, Pnyx, and Lycabettus,—the Acropolis, Anchesmus (now St. George), and the ancient Bulessus. Anchesmus may be estimated at about 1000 feet in height.

The hills of the Piræus, about 100 feet high, and Munychia, about 250 feet, are detached from the remaining heights by a marshy tract, and bound the plain of Athens at the sea on its south-western extremity.

The basis of all this country appears to consist of primary rocks, principally of mica-slate, with granular limestone of several varieties: these constitute the greater part of many of the mountains, and appear in the plains wherever the rock is exposed.

The greater part of Hymettus and Pentelicus is formed of granular limestone. Chlorite slate occurs, in situ, close to Athens: and a compound of felspar and diallage, with other rocks resembling serpentine, is found in detached fragments in the bed of the Ilyssus, and on the west side of Hymettus. Greywacke is observable at the base of the Museum.

Above the primary rocks is a conglomerate, consisting of primary substances imbedded in a calcareous paste, which contains magnesia. The conglomerate is visible, in its place, on the banks of the Ilyssus, at several places on Hymettus, and at Daphne on the western verge of the plain of Athens.

A series of calcareous rocks, including a compact limestone of a splintery fracture, and of various shades of grey and buff, forms the mass and superior part of the range of hills which divides the plain of Athens. Among these hills is found a breccia, composed of fragments of the calcareous substances just now mentioned, united by a reddish calcareous paste, of a texture less solid and uniform than the rock itself. The rocks of this series resemble very closely the calcareous rocks of Gibraltar: and on the north side of Anchesmus a loose spongy rock was observed, which appeared to have been deposited in a fissure; it contained fragments of the limestone, and in its texture, and brick-red colour, was very similar to that which occurs in the crevices of the limestone at Gibraltar. One of the specimens of this description contains a fragment apparently of bone, which brings still closer the resemblance:—and, as at Gibraltar, the limestone rock is sometimes covered with extensive but irregular beds of stalagmite.

The hills of the Piræus and Munychia are composed of a soft calcareous stone, containing magnesia, and including organic remains. A conglomerate still more recent appears to be at present in the progress of formation in some places on the shore.

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11. *Notice accompanying Specimens from the Bermuda Islands. By* Captain Vetch, M.G.S. [Read Feb. 15, 1822.]

In presenting to the Geological Society some specimens from Bermuda, I am induced to accompany them with a short notice, on account of some obvious and interesting inferences to be deduced from them.

The specimens, six in number, were sent me as affording all the varieties of rock to be found in these islands; and as it will appear that they are all composed of fragments of corals and shells of different magnitudes, more or less consolidated by a calcareous cement, it seems probable the Bermudas owe their existence to the accumulation of such materials on a coral reef.

From the extreme narrowness of the channels that separate these islands, they may be regarded as forming but one; and in that case the length will be about thirteen miles, while the greatest breadth hardly exceeds one mile: and no spot is distant so much as five furlongs from the sea. This lengthened narrow shape, with some other peculiarities of form, give the whole so much the character of a coral reef as almost to confirm that conjecture. When it is moreover considered that the Bermudas rise from a shoal twenty-three miles long and thirteen broad, all round which is the deep water of the ocean,—while Carolina, the nearest land, is 700 miles distant, it seems difficult to ascribe the existence of such a platform, thus rising up in the middle of the ocean, to any other origin.

Specimen No. 1. This is composed of the largest fragments, and sometimes presents entire shells more than an inch long, and fragments of coral still larger: the general dimensions of the fragments vary a little on each side of the fourth of an inch. This rock occurs along the shore, and is but loosely aggregated; it seems to pass into—

No. 2; which is in the same loose state of aggregation, but composed of fragments little larger than mustard seed, with larger ones dispersed very sparingly among them.

No. 3. This in the size of the grains is similar to the last; but the grains are firmly agglutinated together by a base, in which may be observed a few minute specks of calcareous spar. The granular appearance is very distant and in small stripes; the cement is nearly wanting, which circumstance serves to connect it with No. 2, of which two rocks I understand the greater mass of the islands to be composed.

No. 4. In this the interstices are almost entirely filled by the cement, so that the granular structure is only to be observed in patches. This rock approaches to the saccharine aspect, and shows many specks of calcareous spar.

No. 5. In this the granular structure of the stone is almost lost; the aspect is truly saccharine, and the surface glistens with calcareous spar.

The five specimens above enumerated afford a perfect gradation from a rough and obviously fragmented rock to a limestone almost compact; and may thus be useful in pointing out the origin of some calcareous beds, in which a similarity of structure exists, but where the mode of formation cannot be traced to operations so recent and so obvious as in the Bermudas. The large grained rock being found along the coast, and the finer grained inland, affords a beautiful confirmation of the assumed origin of the islands; since the accumulation of such materials by surge and winds, would evidently effect that disposition: and as I understand the hills no where exceed 200 feet in height, and are no where so much as five furlongs from the sea, the agents seem quite adequate to this effect.

In enumerating the specimens, I have neglected No. 6,—a yellowish-red coloured limestone of great compactness, in which, though evidently composed of small grains united by cement, the grains are not readily distinguishable, except in patches, or by polishing. This last specimen would carry the gradation a step higher, but I have reason to believe that the stone is of rare occurrence: I am inclined to think that it occurs in patches, and owes its origin in a great measure to the same causes that produce the stalactites of Bermuda.

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12. *Notice on some Fossil Shells from Langton-Green, near Tunbridge Wells.* *By* Sir Alexander Crichton, M.G.S. &c. [Read April 19, 1822.]

These shells are found in a sandstone quarry, worked in the ferruginous sand at Langton-Green, about two miles from Tunbridge Wells, on the Groombridge road. No shells are observed in the substance of the sandstone itself; but they abound in the oval-shaped nodules of ironstone, consisting of oxide of iron, sand, and clay, which the sandstone contains. These nodules are from one and a half to two feet in their longest diameter, and from ten to sixteen inches in their transverse diameter. They split with ease transversely, into slices of various thickness, and wherever they divide exhibit innumerable sharp casts and impressions of small bivalve shells, of which the calcareous matter has altogether disappeared.

The author also states, that in sinking a well at Tunbridge Wells, at the place called North Grove, a thin seam of coal was found at the depth of 50 or 60 feet.

ALERE FLAMMAM.

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EXPLANATION OF THE PLATES.

PLATES I. & II.

Illustrate Mr. Strangways' paper on the geology of Russia, Art. I. page 1, &c. of the present volume.

Plate I.

Fig. 1. represents veins of hornblende in limestone, near the western extremity of the island of Pargas: described pages 3 and 4.

Fig. 2. Map of the falls of Msta, at the village of Ouglova, near Borovichy, in the Valday hills: pages 13, 14, 16.

Fig. 3. View from the hill of Simbirsk on the Volga, page 30—showing the relative situation of the white marl, sand, and black clay. The rocks in the distance are the white central limestone, forming the high steppe of Pallas, and marked H on the map, Plate II.

Plate II.

A sketch of a geological map of European Russia. To facilitate reference, a letter is annexed to each colour in the table on the margin of the plate; and the several portions of the map in which the same rocks occur are denoted by corresponding letters as well as colours.

PLATES III. IV. V. VI. VII. & VIII.

Illustrate Mr. De la Beche's paper on the south coast of England, Art. II. page 40, &c.

Plate III.

Fig. 1. represents the remains of a crustaceous animal, found in compact nodules of the green sand, in the vicinity of Lyme: p. 42.

Fig. 2. The back of a singular fossil crab, from the same place, found in the green sand: p. 42.

Figs. 3, 4, & 5. The Echinonäus lampas, a new species of Echinite, from the green sand near Lyme, mentioned page 42. Fig. 3. the upper surface: fig. 4. a side view: fig. 5. the under-side of the fossil.

EXPLANATION OF THE PLATES.

Plate IV.

Figs. 1 & 2. Fossil bodies, which appear to have the external defensive organs of some fish, found in the lias near Lyme: p. 43.

Fig. 2. exhibits the alternate position of the teeth-like processes in two rows, seen in profile in fig. 1.

Fig. 3. A transverse section of fig. 1. at *b*.

Figs. 5, 6, 7, 8, 9 & 10. Fossil bodies resembling palates or teeth, found in the lias, near the fossil represented in figs. 1 & 2: figs. 4 & 5 are rare varieties: fig. 6 the most common.

Plate V.

Figs. 1 & 2. The side and front views of a very rare fossil, which appears to belong to the same class with that represented in Plate IV. figs. 1 & 2.

Fig. 3. A fossil jaw with a triple row of teeth, from the lias of the neighbourhood of Lyme; in the collection of Colonel Birch.

Fig. 4. shows the position of the four rows of teeth in another specimen, similar to fig. 3; in the same collection.

Plate VI.

Fig. 1. represents a specimen of the Dapædium politum, described p. 45: the interior of the mouth is shown in fig. 2, and two of the teeth in fig. 3.

Fig. 4. The inner side of two contiguous scales of the Dapædium politum, showing the acute process, which projects from each scale and fits into a corresponding depression in the adjoining one. These processes are not visible on the outside. —page 45.

Plate VII.

Fig. 1. Another fossil fish from the lias near Lyme: p. 45.

Figs. 2 & 3. Fossil ferns, from the lias of Axminster in Devonshire, in the collection of Professor Buckland.—Drawn by Mr. Sowerby. Fig. 2. is from the white: fig. 3. from the blue lias.

Plate VIII.

Sectional views of the coast of Dorset and Devon, from Bridport Harbour on the east, to Sidmouth on the west; with colours indicating the several rocks.

PLATES IX. X. & XI.

Illustrate Mr. De La Beche's paper on the coast of France, Art. VI. p. 73, &c.

Plate IX.

Figs. 1, 2, & 3. Sections, on the lines AB, CD, and EF, on the map, Plate XI. The scale of horizontal distances is the same with that of the map; but that of the heights much greater. The colours denoting the rocks correspond with those of the map.

Fig. 4. An undescribed Ammonite, from the blue clay of the oolite formation at the Vaches Noires cliffs: pp. 77 and 78.—*b.* represents a portion of the edge.

Fig. 5. A specimen of the Hallirrhöe costata of Lamouroux, showing the interior structure; from the green sand of the Vaches Noires cliffs: p. 75.

Plate X.

Sections of the coast of France, from Fecamp, in the department of the Seine Inferieure, to Grand Camp, in the department of Calvados: p. 73. The scale is considerably larger than that of the map, Plate XI. The colours indicating the rocks correspond with those in the map.

Plate XI.

Geological map of portions of the departments of the Seine Inferieure, the Eure, Calvados, and La Manche. The colours correspond with those of the sections Plates IX. and X.

PLATE XII.

Illustrates Mr. Webster's paper on the Fresh-water Formation in Hordwell Cliff, &c. Article VII. p. 90.

Fig. 1. represents a section of the coast of Hampshire, from Hurst Castle to Muddiford. The scale of heights is greater than that of lengths.

Fig. 2. A Map of the coast of which fig. 1. is a section, together with a small part of the Isle of Wight.

Fig. 3. represents the magnified appearance of some fossil bodies found in the fresh-water formation at Hordwell: pp. 92, 93.

Fig. 4. The same bodies of their natural size.

PLATES XIII. & XIV.

Illustrate the Rev. William Buckland's paper on the Excavation of Valleys, &c. Art. VIII. p. 95.

Plate XIII.

Map of the Valleys which intersect the coast of Dorset and Devon.—The N. W. angle, not being mentioned in the paper, is not coloured.

Plate XIV.

Fig. 1. Section of the coast of Dorset, from Lyme Regis to the Isle of Portland, as seen from Lyme Regis; showing the manner in which the valleys are intersected at the point where they are terminated by the present sea shore. It is probable that a considerable portion of this coast has been worn away by the sea, and that the small clay valleys or combes, which are now abruptly truncated at their termination, were originally continued with a gradual slope to the water's edge. The form of these cliffs and of those represented in fig. 2, as seen from a boat in passing along the coast, is represented in the sections by Mr. De la Beche, Plate VIII. of the present volume.

Fig. 2. Section of the coast of Devonshire, from Sidmouth to Beer-head. The first combe or dry valley, on the E. of Sidmouth, is abruptly truncated, like those represented in fig. 1.; the others terminate by a gradual slope in the sea. The line of junction of the green sand with the red marl is marked by the termination of inclosures and of fertile soil, exactly at the point where the green sand begins. The table lands that form the summits of these green sand hills are for the most part barren heaths, except where they are covered with diluvian gravel, or by a bed of unrolled chalk flints. This observation applies also to the green sand summits in fig. 1,—and to the table lands composed of the same stratum, which stretch inland from the coast to the flat summits of the Black Down hills,—in which this formation attains its highest elevation, overhanging with its escarpment the vale of Taunton.

PLATES XV. XVI. XVII. XVIII. XIX. XX. XXI. & XXII.

Illustrate the Rev. Mr. Conybeare's additional Notices on the fossil Genera Ichthyosaurus and Plesiosaurus, Article IX. p. 103.

General Letters of Reference.

Throughout the series of plates illustrating the former * and the present Memoirs on the genera Ichthyosaurus and Plesiosaurus, the same letters have been employed in reference to the several bones which compose the skeleton of the head; being those previously applied in a similar manner to the osteology of the Crocodile's head by M. Cuvier. It may be convenient to the reader to have these references at once under his eye: the author has therefore added the whole alphabetical series,—although some of the bones, designated by particular letters, are not visible in the present plates,—with the intention of continuing the same references in any future plates of the heads of other saurian animals; which will secure the double advantage of making the present list a complete index to the osteology of the head in the genera of this order, and of rendering any future table of reference unnecessary. The bones not

* Geological Transactions, Vol. V. p. 559.

visible in the present plates, are distinguished by an asterisk prefixed to the letters.

a. Intermaxillary bones.

b. Maxillary.

N.B. It would have been a far more convenient order to have introduced next to these bones, the nasals *k k*, and the lachrymals *i i*.

c. Jugal.

Bones visible only in the roof of the mouth.

**d.* External pterygoids; not visible in the present Plates.

e. Palatal bones.

f. Internal pterygoidal processes.

**g.* Bones considered by M. Cuvier as the great wings of the sphenoid. By instituting a comparison with other oviparous quadrupeds, I have become convinced that these correspond with the lamellar bones in the turtle united to the parietal; and that they are the same parts which are reduced to two cylindrical columns in the lacertæ: I should therefore be inclined to name them lateral-parietals. They are not visible in the specimens now represented.

Dismemberments of the frontal bone.

H. Middle frontal.

h. Anterior frontals.

h'. Posterior frontals.

N.B. These bones, in the Ichthyosaurus, send a long process forwards beneath the anterior frontals,—which emerges thence and re-appears in front of the upper part of the orbit, and might without due care be mistaken for a separate bone. See Plate XVII.

h''. Post orbital frontal process.

i. Lachrymals, or Ossa unguis.
k. Nasals: } These would have been more properly placed next to *b*, the maxillaries.

**l.* This letter is not appropriated by M. Cuvier. I shall hereafter apply it to the Os petrosum; which in all oviparous quadrupeds, as indeed in some Mammalia (*e. g.* the ruminantia), is a separate bone.

m. Parietal. I should consider this as the middle parietal, and (as I have before observed) the bones marked *g* as lateral parietals.

Dismemberments of the temporal bone.

n. Squamoso-zygomatic portion.

n'. Mastoid process,—connected with the preceding in the crocodile; but in most other oviparous quadrupeds forming a separate bone.

o. Tympanal bone, or Os quadratum.

N.B. The Os petrosum, to which I have assigned the vacant letter **l*, ought here to follow.

p. A bone connecting the tympanal bone and the posterior part of the jugal bone; peculiar, I believe, to the crocodile.

Dismemberments of the occipital bone.

- *q*. Superior occipital.
- *r*. Inferior occipital.
- *s*. Lateral occipitals.
- **t*. Basilar portion of the sphenoid. } Not visible in these specimens.
- **t'*. Process corresponding to the sella turcica. }

N.B. M. Cuvier seems (for his notice is very slight) to have considered these last two bones, together with the internal pterygoid, and the bones marked *g*, as forming in the crocodile a single and united sphenoid. But in the common Nilotic crocodile they are certainly distinct bones, the sutures between them being very evident. These sutures are clearly exhibited in a specimen in my possession, and may be traced in the figure given by Scarpa (de Auditu); they closely correspond to the similar parts in the turtle.—See Bojani, Anatome Testudinis.

Bones of the lower jaw.

- *u*. Dental.
- *v*. Angular.
- *x*. Coronoid.
- *y*. Articular.
- *z*. Crescent-shaped.
- *&*. Opercular.

The letters above given, having been adopted merely for the convenience of reference to M. Cuvier's plates of the osteology of the crocodile, are not systematically disposed. The transpositions which a more natural arrangement would render necessary are indicated in the foregoing list.

Particular Figures.

Plate XV.

Illustrates the dentition of Ichthyosaurus.

Figs. 1 & 2 show the succession of the new teeth in the crocodile: see p. 106.

Fig. 3. The same in the fossil Saurian of Maestricht; selected as an example of the common lacertian type: page 106.

Figs. 4, 5, 6. The same in the Ichthyosaurus: pp. 106, 107.

The following figures illustrate the teeth of the different species.

Fig. 7. Tooth of Ichthyosaurus platyodon: page 108.
8. ——— I. communis, ... *ibid.*
9. ——— I. intermedius, ... *ibid.*
10. ——— I. tenuirostris, ... *ibid.*

Fig. 11. Probably a tooth of Plesiosaurus: p. 120.

Fig. 12. A part of the dental bone of the lower jaw; showing the mode in which the teeth are lodged, and the canals for the distribution of the branches of the inferior maxillary nerve: p. 109.

Fig. 13. Transverse section of an adult tooth of I. communis; showing the filling up the interior cavity by the ossification of the pulpy substance: p. 107.

Plate XVI.

Figs. 1 to 5. A series of transverse sections derived from the anterior portion of a large jaw of I. platyodon: p. 112.

Fig. 6. Side view of the same jaw: *ibid.*

Fig. 7. Inferior view of the same; the posterior part restored from another individual of the same species.

Fig. 8. Posterior part of a large head of I. communis belonging to the Oxford Museum: the lower jaw is described p. 112; the parts surrounding the tympanal cavity, p. 116; and the occipital bones, p. 117.

Figs. 9 to 13. Transverse sections of the lower jaw, derived from the preceding specimen: p. 112.

Fig. 14. Internal view of the posterior part of the lower jaw, from the same specimen: p. 111.

N.B. In the text this is erroneously described as the jaw of the left side; being in fact the right.

Plate XVII.

Head of Ichthyosaurus intermedius; a matchless specimen belonging to Mr. De la Beche. The sternal parts of the same specimen have been figured in the Philosophical Transactions for 1819—Plate 14. This specimen is referred to throughout the description of the bones forming the head in the Ichthyosaurus; and more especially for those exhibited in the roof of the mouth: see p. 117. The dislocation of the parts connected with the tympanal and occipital portion is explained in the note, p. 116.

Plate XVIII.

Three views of the dental bone of the lower jaw in the Plesiosaurus: p. 119.

Plate XIX.

Figs. 1 & 2. An entire head of Plesiosaurus, under two points of view: pp. 120, 121.

Fig. 3. A detached tooth: p. 120.

The middle figures, A & B, exhibit an attempt to restore the head: see p. 121.

Plate XX.

Fig. 1. Paddle of Ichthyosaurus: p. 118.

Fig. 2. Three views of the lower occipital bone, containing the condyle of the Ichthyosaurus: p. 117. *a.* shows the exterior and posterior extremity; *b.* the bone laterally, exhibiting the basilar process; *c.* the upper and interior surface.

Plate XXI.

Figs. 1, 2, 3. Posterior extremity of a jaw, probably of Plesiosaurus; belonging to Colonel Birch:—described p. 122. 1. The superior surface; 2. outer side; 3. inner side.

Figs. 4, 5, 6. Humerus of peculiar form, found with the preceding: p. 122.

Plate XXII.

Fig. 1. Femur of Plesiosaurus. *Fig.* 2. Os pubis. *Fig.* 3. Os ilium. All described p. 122.

Figs. 4 to 8. A series of vertebræ from the Kimmeridge clay; found both near Weymouth and at Heddington; probably belonging to a new species of Plesiosaurus: see p. 123.

PLATE XXIII.

A Map of part of the course of the river Sutluj, in the Himálaya mountains; in illustration of Mr. Colebrooke's paper, Article X. p. 124.

This map, as well as part of Plate XXIV, will serve also to illustrate Mr. Fraser's Notes on the Himálaya Mountains,—Vol. V. p. 60.

PLATE XXIV.

Fig. 1. A Map of part of India, in illustration of some of the papers published in the Geological Transactions; the routes or tracts of country referred to being denoted by different colours.

1. *Yellow*,—denotes the tract described in Mr. Colebrooke's paper, Art. X. p. 124, of the present volume; showing the connexion of the valley of the Sutluj, represented on a larger scale in Plate XXIII, with the adjoining country.
2. *Brown.*—Mr. Fraser's route from Delhi to Bombay, described in his paper, Art. XII. p. 141.
3. *Green*,—points out the parts of the N.E. of Bengal, referred to in Mr. Colebrooke's paper, Art. XI. p. 132; and in Mr. Scott's Letter, Art. XIII. p. 167, of the present volume.
4. *Blue*,—denotes the tract described in Dr. Adams's paper on the geology of the banks of the Ganges, from Calcutta to Cawnpore, Vol. V, Art. XVII, p. 346.
5. *Red.*—The Island of Salsette:—Mr. S. Babington's paper; Vol. V. p. 1.

Fig. 2,—from a sketch by Mr. Fraser, illustrates the structure of the basaltic heights described at p. 158 of Mr. Fraser's paper, Art. XII. of the present volume.

Fig. 1.

Disjointed hornblende veins in the limestone of Pargas

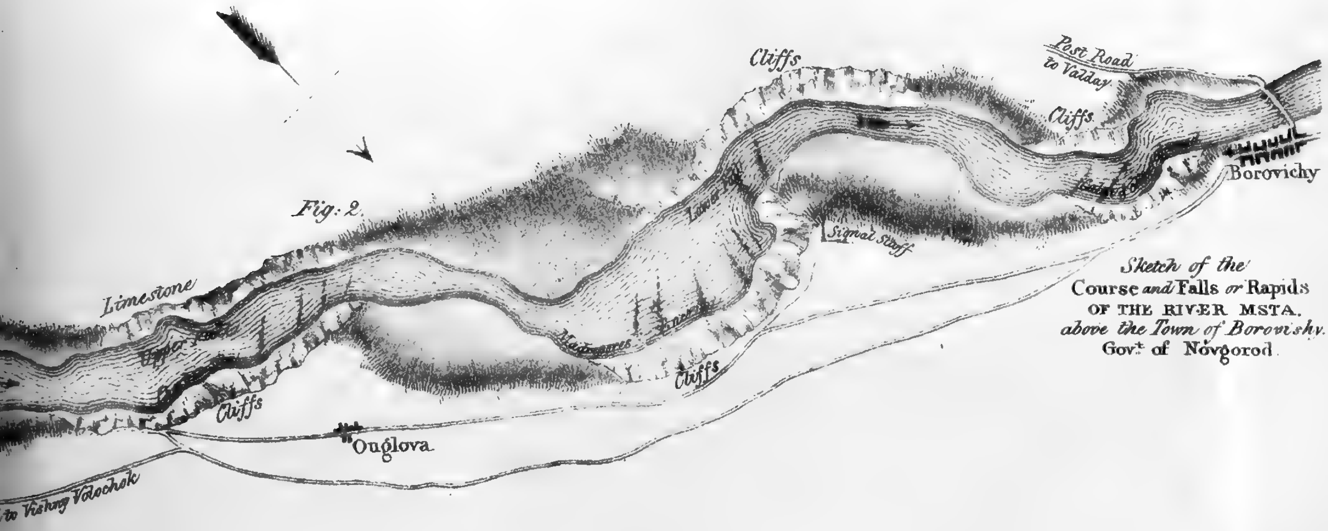


Fig: 2.

Sketch of the Course and Falls or Rapids OF THE RIVER MSTA. above the Town of Borovichy. Govt. of Novgorod.

Fig: 3.

Kreide mergel of Pallas } Without Shells
Pale red sand

Black Shale } With Ammonites, &c.
Black Clay

The white Rocks in the distance are the white lime-stone of the High Steppe.

Drawn by the Honble. Will: T.H.F. Strangways. J.D. Harding Lithog.

View from Simbirsk, looking down the Volga, towards the High Steppe of Samara.


SKETCH,
to serve as a Basis for a
GEOLOGICAL MAP
OF
EUROPEAN RUSSIA.
Coloured to shew the connections of its Strata with those of the surrounding Countries.
A Primitive
B Marble Breccia
C Jasper Breccia
D Comp'ed sand stone on L. Onega and the Caucasus
L. Ladoga & Onega
E Transition Lime
F Green Shale or Sand
G Blue Clay
L. Onega to Norway
H Limestones of the central parts of Russia, differing slightly in character, but probably one formation
I Red Marl, with Salt and Gypsum
K Belemnites &c
L Chalk, or Limestone so called by Engelhardt & others
M Shelly limestones of the Southern Steppes & the Crimea, perhaps beds above the Chalk
N S.E. extremity of the High Steppe of Pallas, uncertain whether connected with M or with H
O Coal, Naphtha or Bituminous Slate
P Brown Sandstone of Limberg, containing Shells
Q Slate
R Conglomerate
S Comp'd limestone
Crimea & Caucasus
T Copper sand
V Floetz trap
X Oolitic character
LAPLAND
WHITE SEA
GULF OF BOTHNIA
FINLAND
GULF OF FINLAND
NORWAY
BALTIC
SIBERIA
LITTLE KNOWN
LITHUANIA
POLAND
LITTLE RUSSIA
VOLHYNIA
GALLICIA
CARPATHIAN MOUNTAINS
HUNGARY
TRANSYLVANIA
MOLDAVIA
BESSARABIA
VALACHIA
BULGARIA
BLACK SEA
SEA OF AZOF
CRIMEA
CIRCASSIA
CAUCASUS
GEORGIA
CASPIAN SEA
LAKE ARAL
KHANATE OF KHIVA
TROUKHMEN
KIRGHES
SALT STEPPE
Copper Sand
Central district of Iron Mines
Primitive Boulders & Chalk Flints
Boulders of various kinds over all the Countries North of ...
High Land perhaps formerly a large Island
Longitude E. from Greenwich
W.T.H.F.S.
B.R. Baker Lithog.
Printed by C. Hullmandel

Fig: 1

Fig: 2.

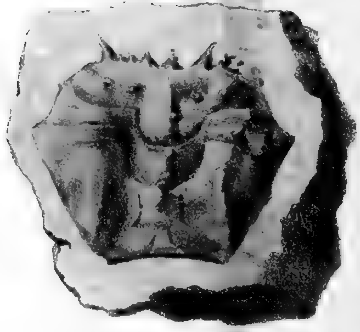
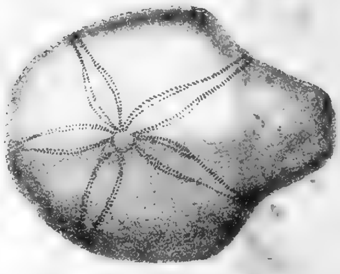


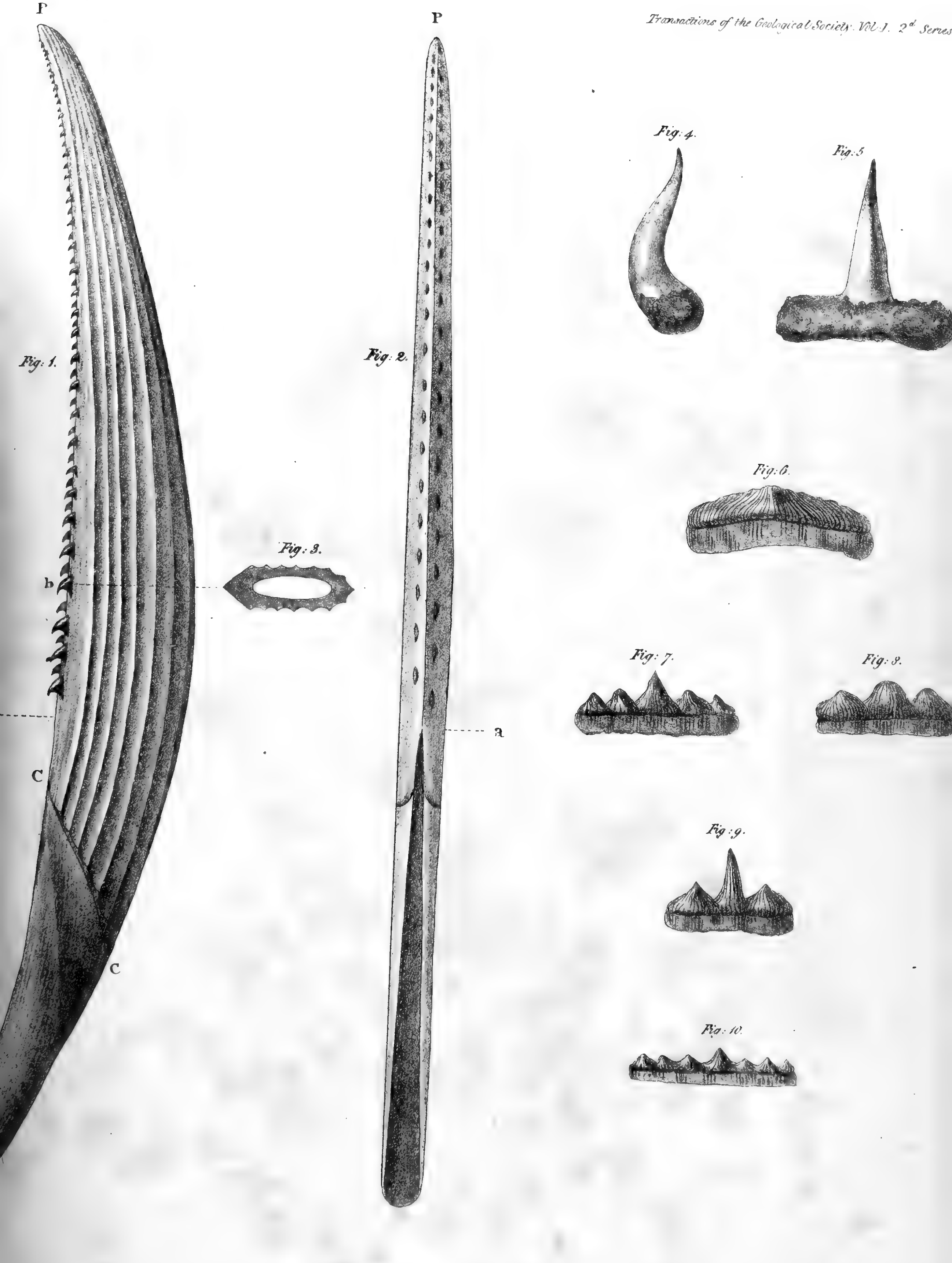
Fig: 3.

Fig: 4.

Fig: 5.



H.T. De la Beche del.   Printed by C. Hullmandel   G. Scharf. Lithog.



Beche del

Printed by C. Hullmandel.

G. Scharf Lithog.

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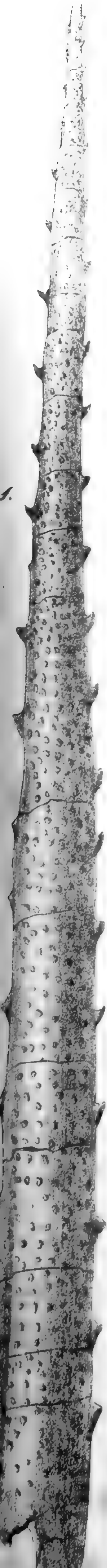

Fig: 2.

Fig: 3.

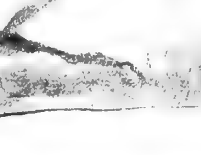

Fig: 4.

H. T. De la Beche del.

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G. Scharf Lithog.

Fig: 1.

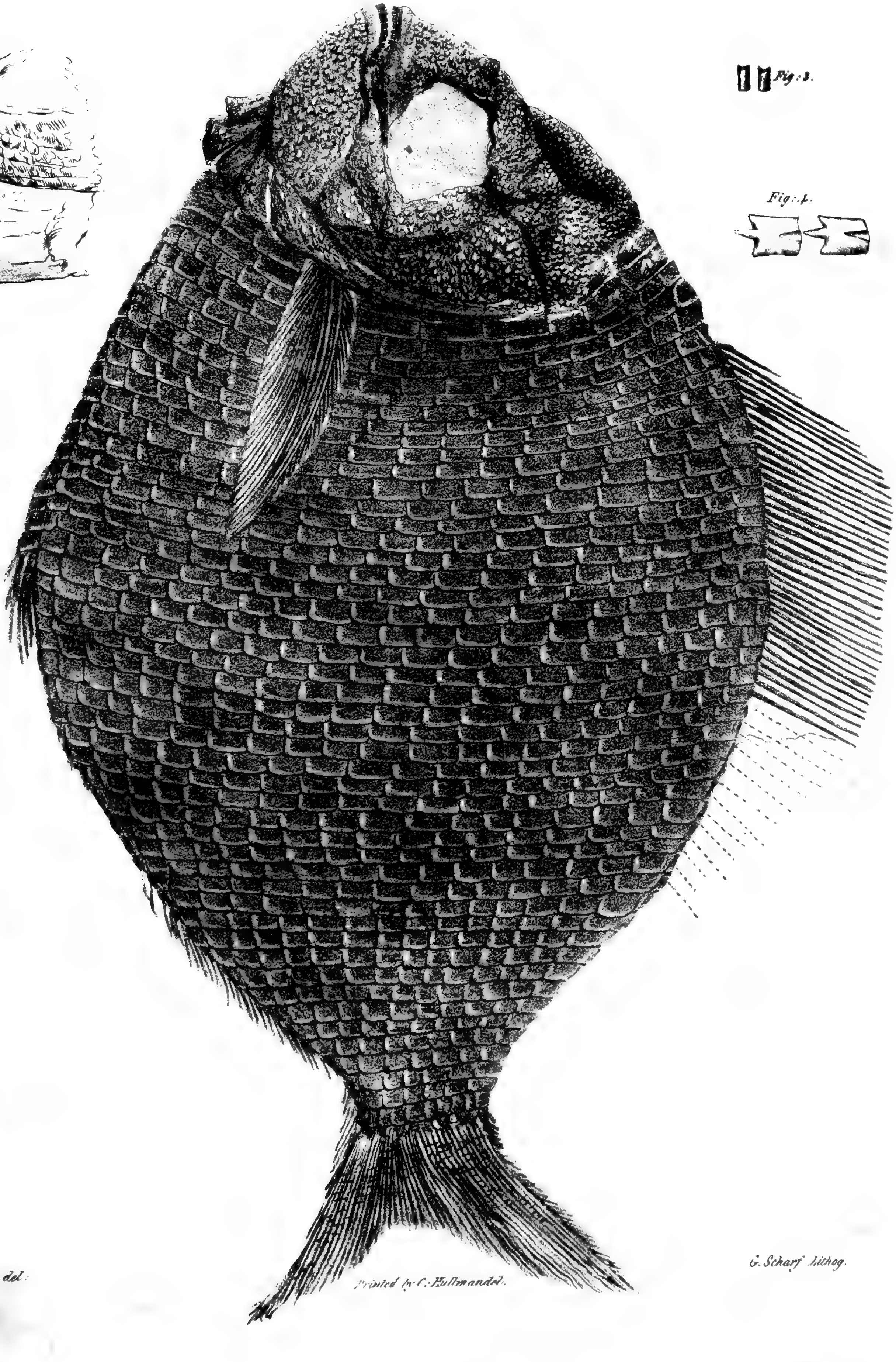

Fig: 3.

Fig: 4.

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Fig. 1

Fig. 2

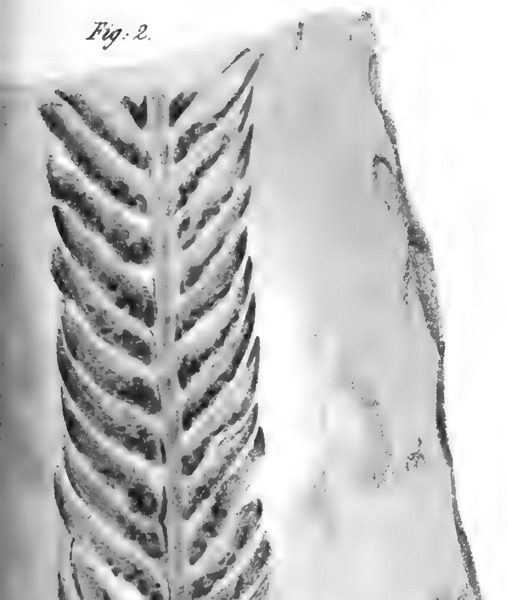
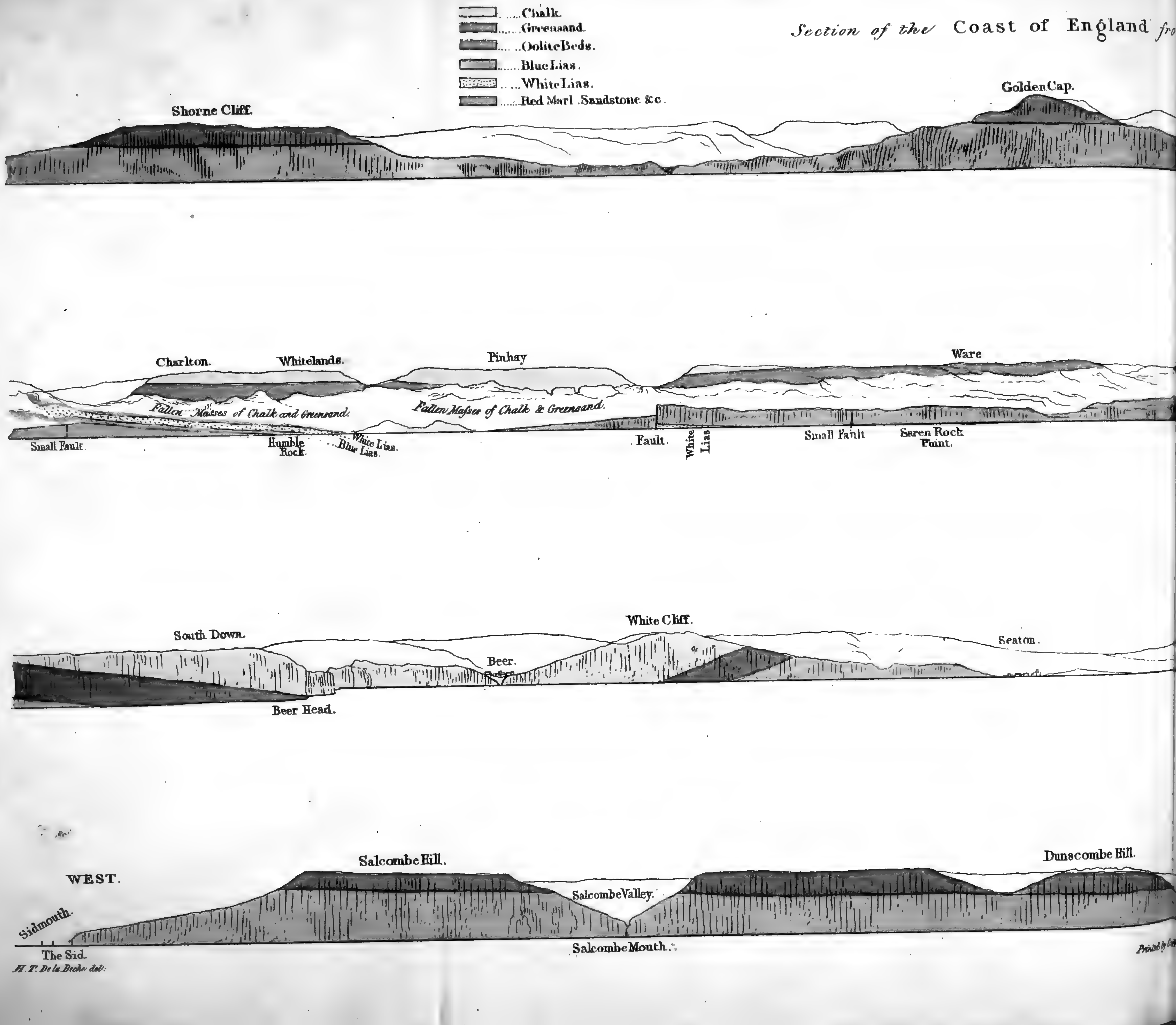


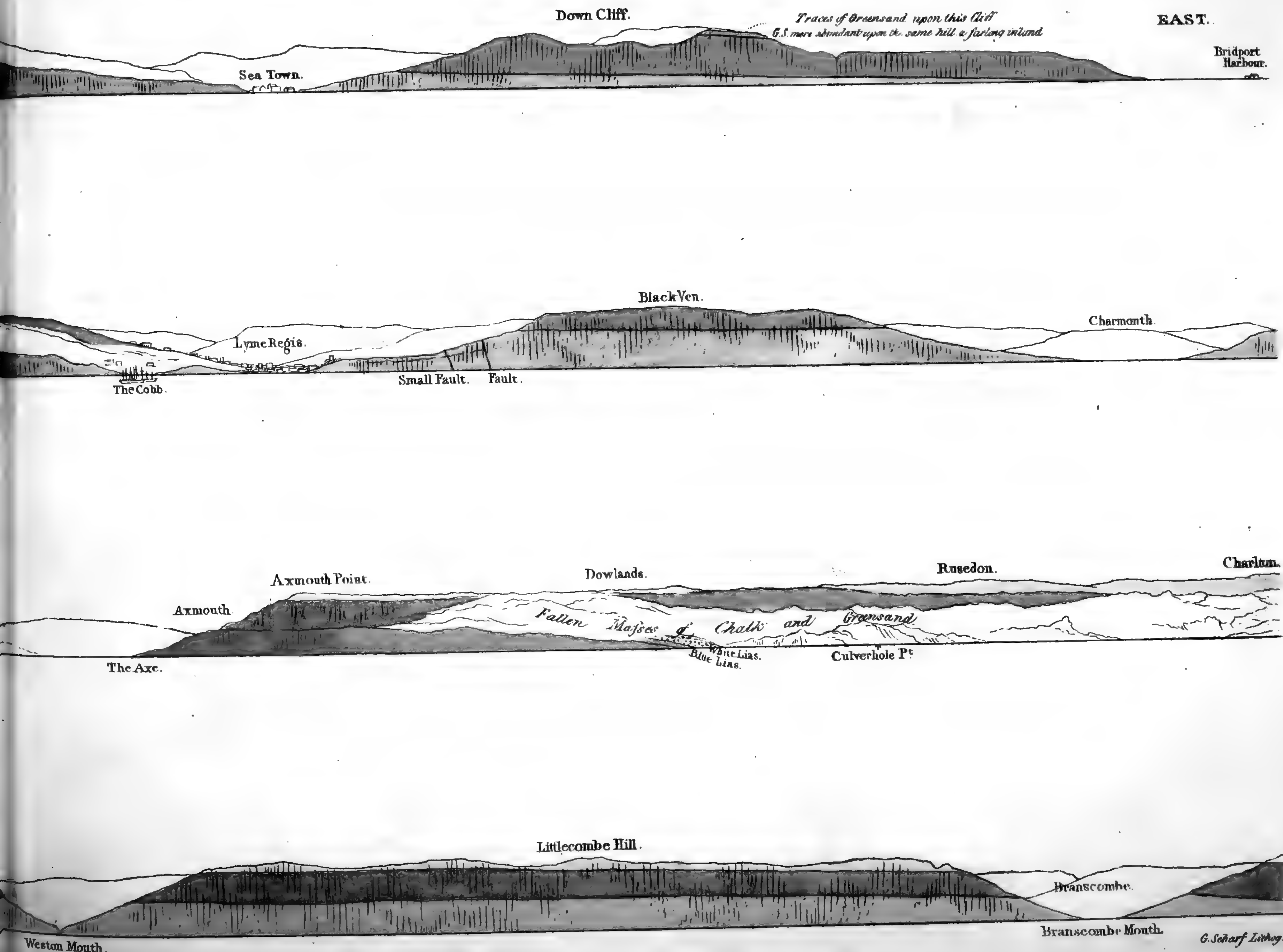
Fig. 3

De la Beche, del: Printed by C. Hullmandel.   G. Scharf Lithog:



Section of the Coast of England from
Chalk.
Greensand.
Oolite Beds.
Blue Lias.
White Lias.
Red Marl. Sandstone &c.
Shorne Cliff.
Golden Cap.
Charlton.
Whitelands.
Pinhay
Ware
Fallen Masses of Chalk and Greensand.
Fallen Masses of Chalk & Greensand.
Small Fault.
Humble Rock.
White Lias.
Blue Lias.
Fault.
White Lias
Small Fault
Saren Rock Point.
South Down.
White Cliff.
Beer.
Seaton.
Beer Head.
Salcombe Hill.
Dunscombe Hill.
WEST.
Sidmouth.
Salcombe Valley.
The Sid.
Salcombe Mouth.
H. T. De la Beche del:

Bridport Harbour to Sidmouth.

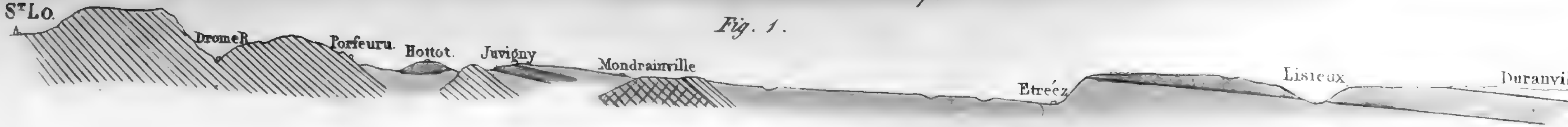


Hullmandel.

G. Scharf Lithog.

Section from St. Lo to Lisieux.
on the Line marked A.B on the Map.

Fig. 1.

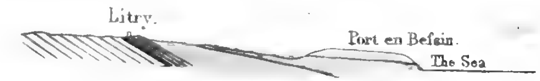


Section from Condé sur Noireau through CAEN to the Sea.
on the Line marked C.D. on the Map.

Fig: 2.

Section from Litry to Port en Befsin.
on the line marked E.F on the Map.

Fig: 3.



Chalk.
Coal Measures.
Green Sand Formation
Old Red Sandstone.
Oolite Formation
Transition Limestone.
Lias.
Quartz Rock.
New Red Sandstone Formation
Grauwacke & Slate
Porphyritic Conglomerate.

Fig: 4.

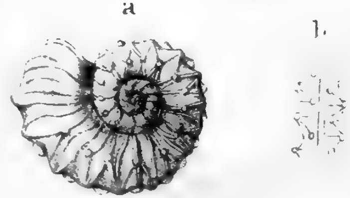


Fig: 5.

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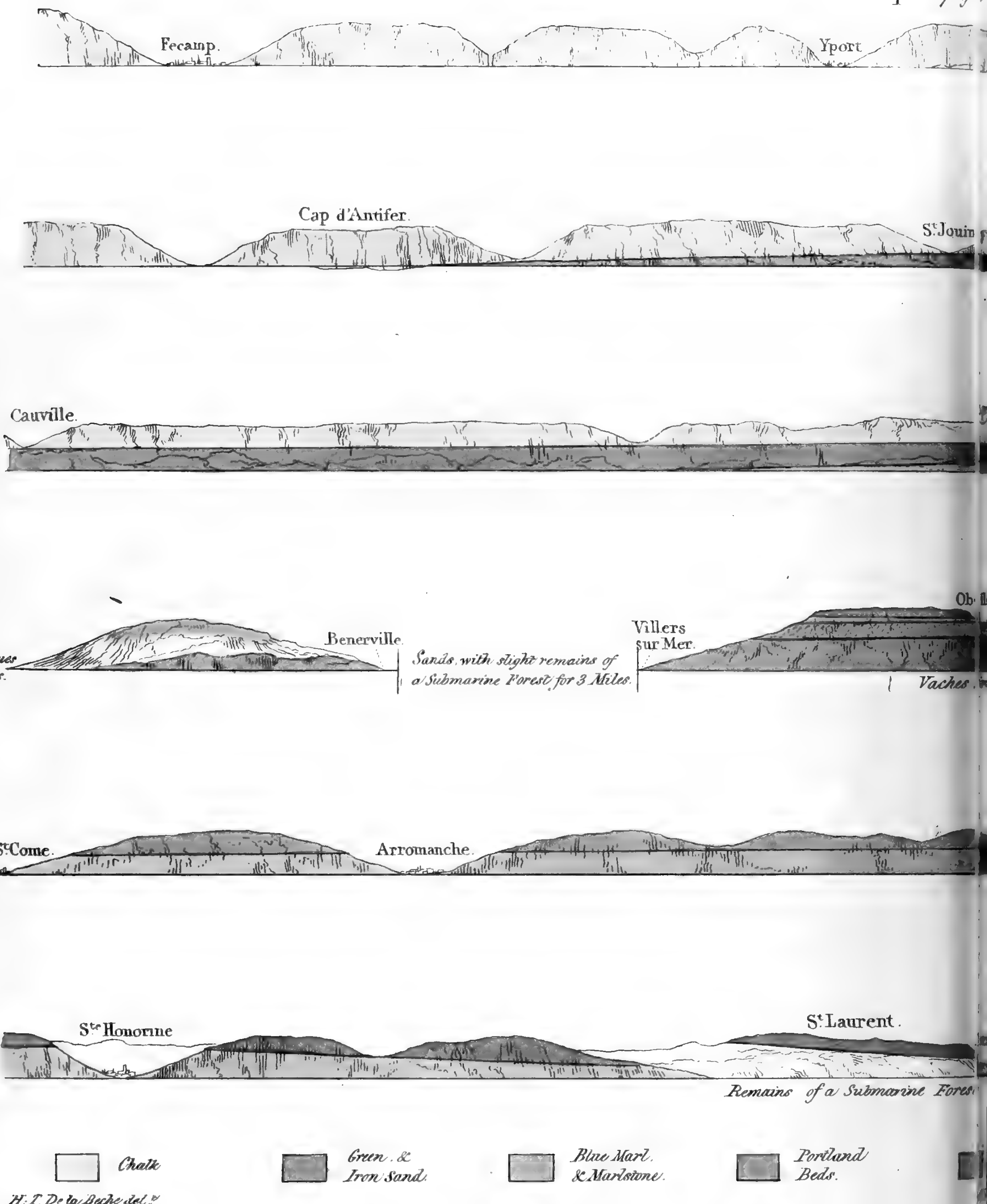
Coast Section, from Fecamp (Dep.t of



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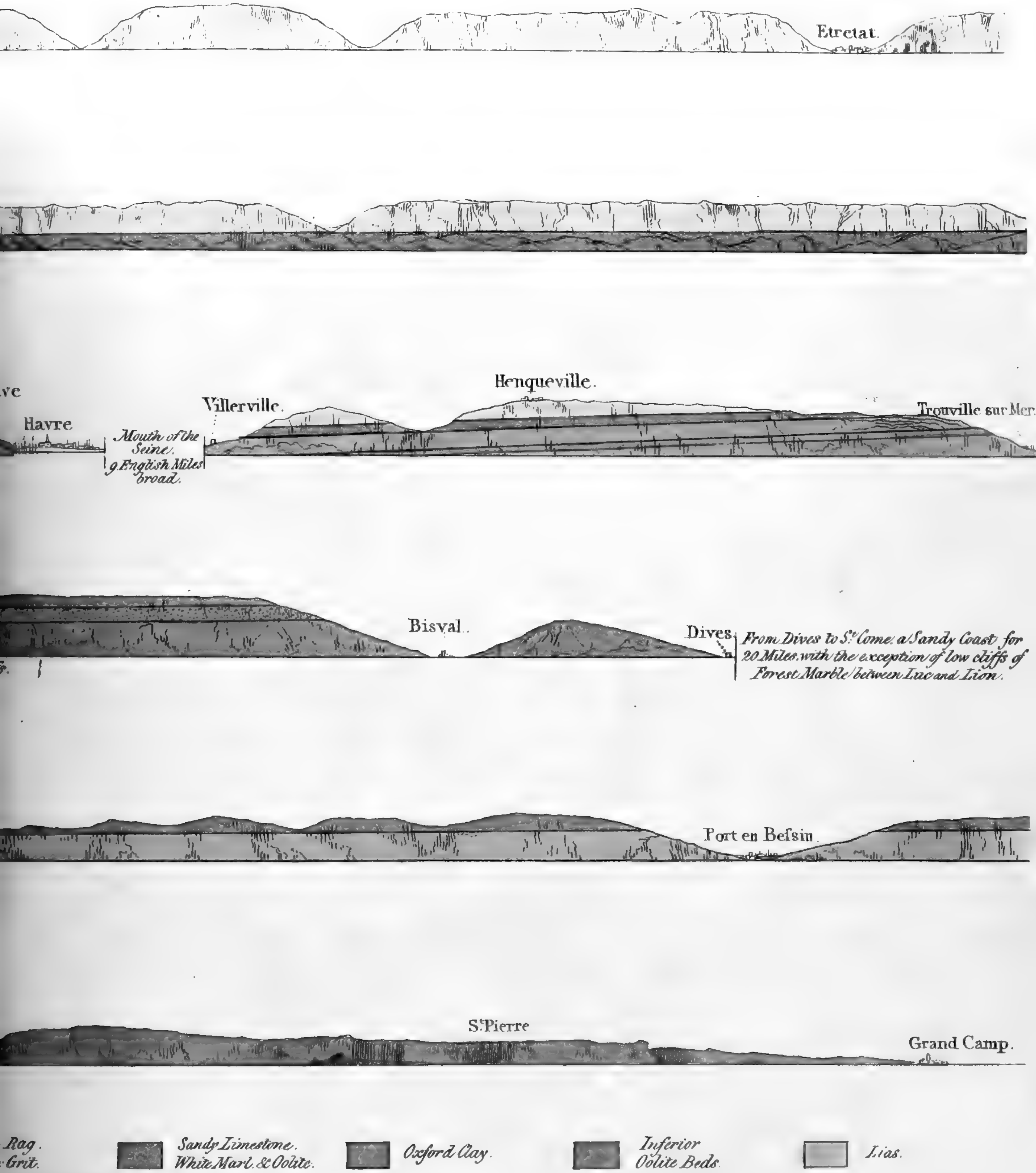

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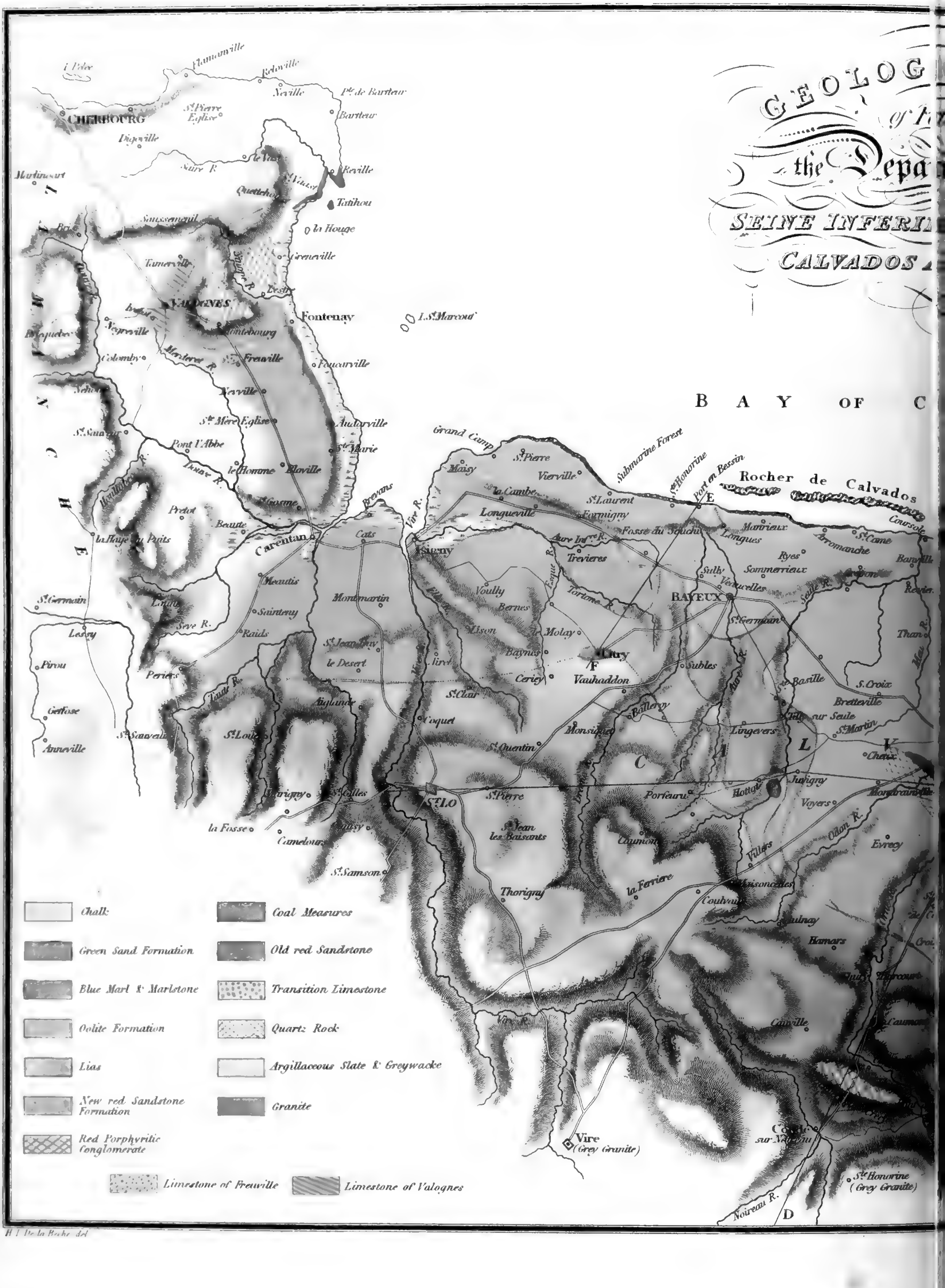
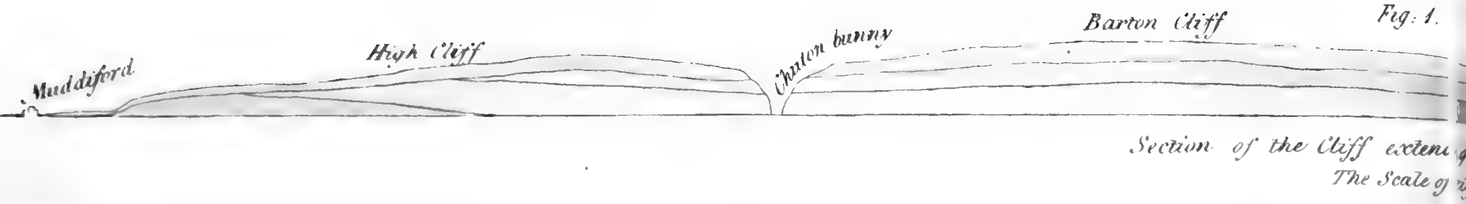
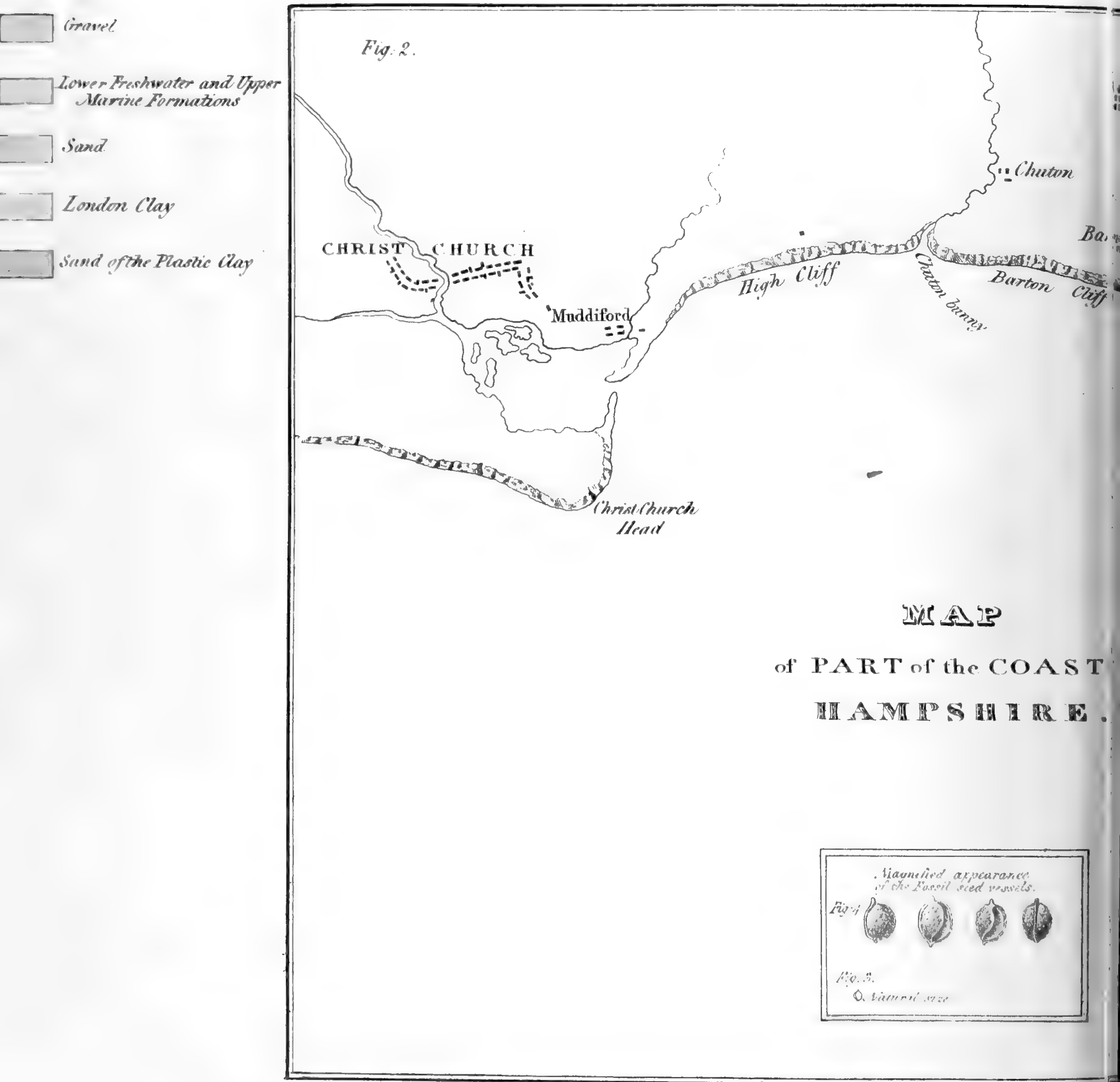


H. T. De la Beche del.

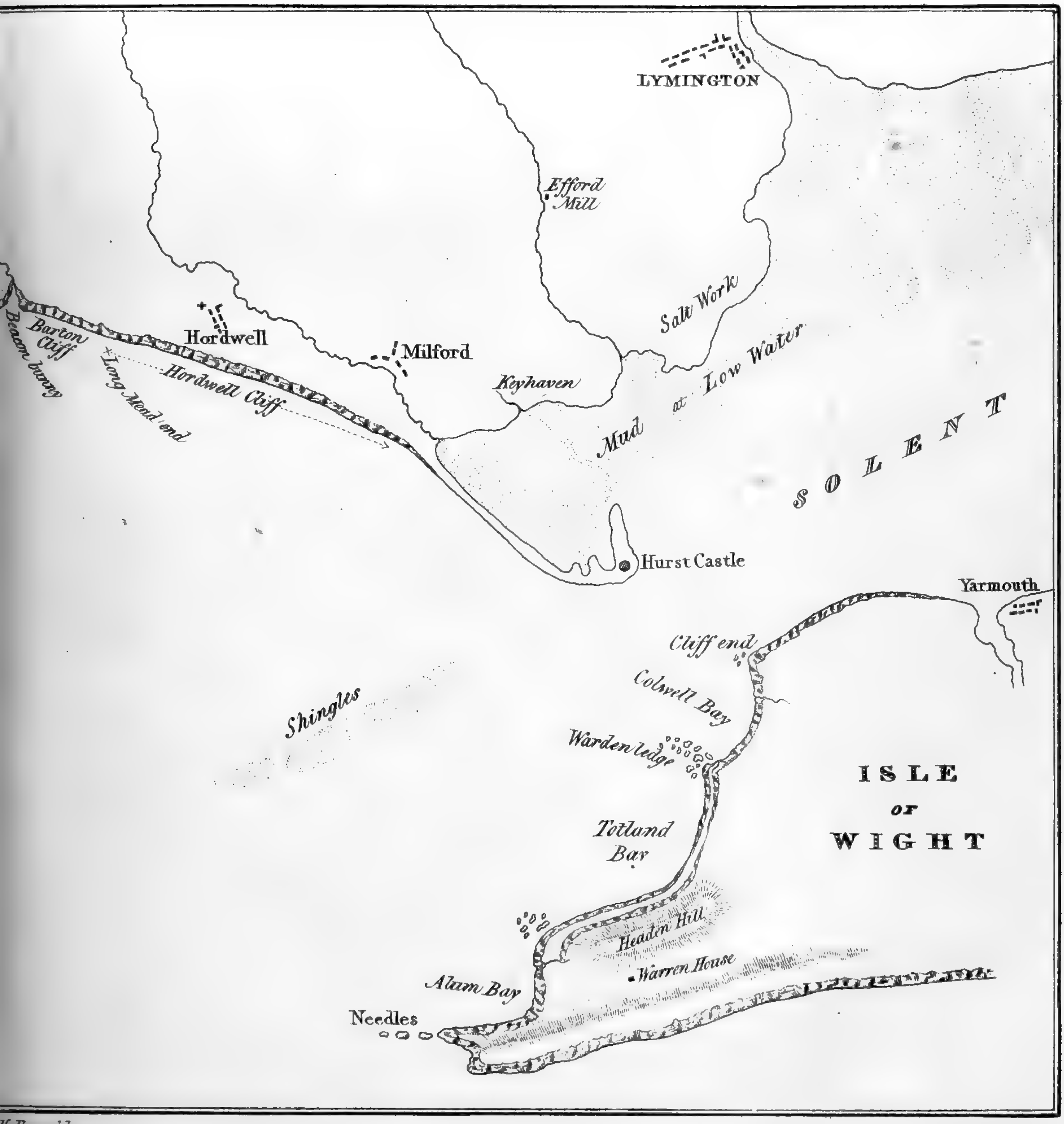

AL MAP
nts of the
E. THE EURE,
A MANCHE.
LVADOS
SEINE INFERIEURE
Fecamp
Yport
Etretat
C. d'Antifer
St. Jouin
C. la Hève
(Fossil Crocodile)
LE HAVRE de Grace
Montivilliers
Harfleur
Bolbec
Lillebonne
Caudebec
YVETOT
Embouchure de la Seine
Marl with Green Sand
Fallen masses of Chalk and Green Sand
Honfleur
Villerville
Henqueville
Traces of a Submarine Forest
Villers sur Mer
Fossil Crocodile & Plesiosaurus
(Vaches Noires)
Cabourg
Pont l'Eveque
Pont Audemer
Lisieux
Bernay
Brionne
FALAISE
EURE
Dives R.
Orne R.
Touques R.
Calone R.
Rille R.
B
C
5
10
20
30
Scale of British Statute Miles 69½ to a degree.
J. Cross sculpt. Cursitor Str.





Drawn by T. Webster

Muddiford to near Hurst Castle.
double that of Lengths.



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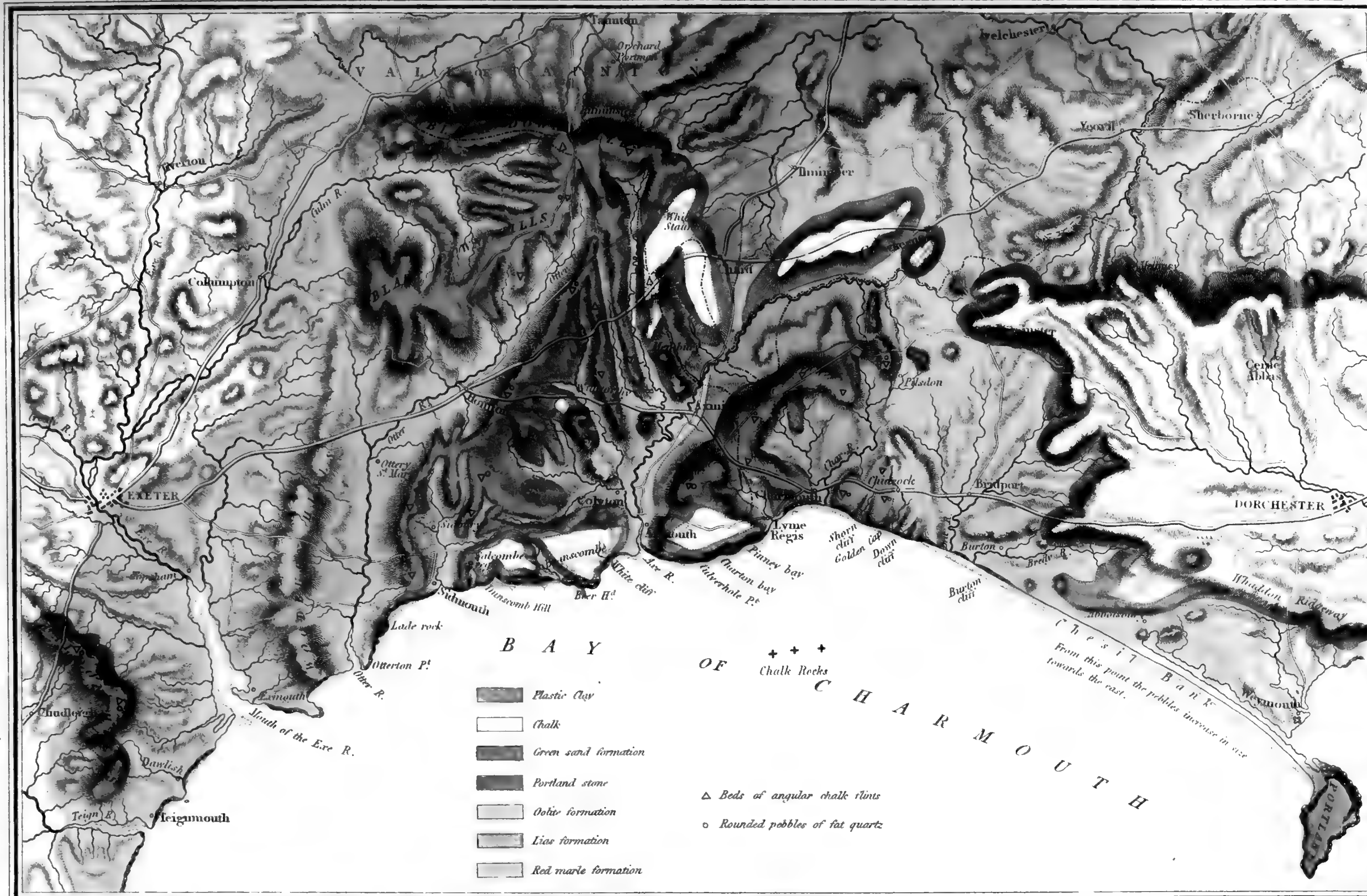
B.R. Baker Lithog.



MAP of the COUNTRY adjacent to the COAST of DEVON and DORSET from TEIGNMOUTH to PORTLAND.

Blue Lias.

Oolite

Green sand.

Section of the Coast of Dorset *f*

Drawn by H. Cornish Esq.

Section of the Coast of Dev

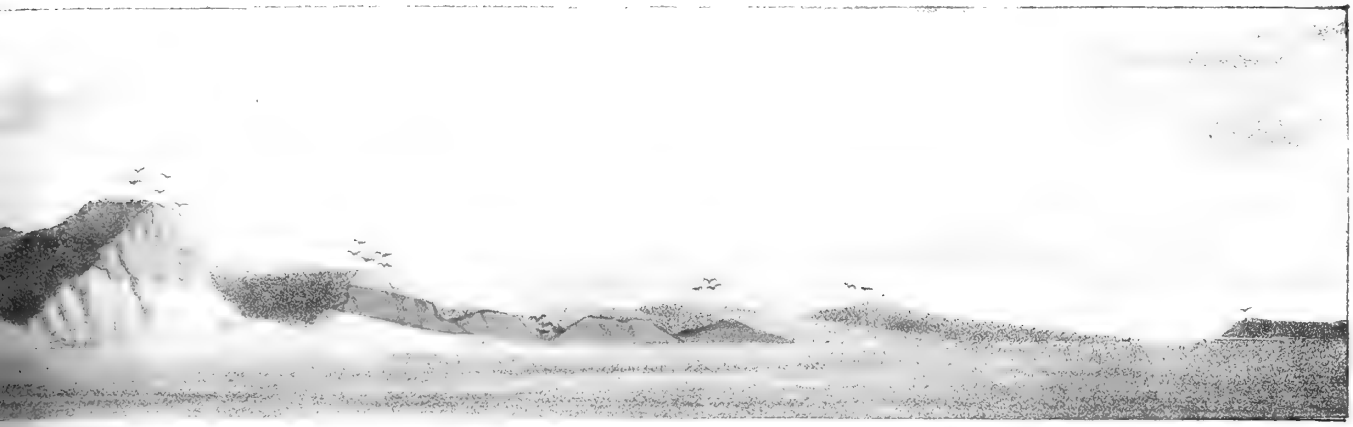
Red Marl.

Green sand.

Chalk.

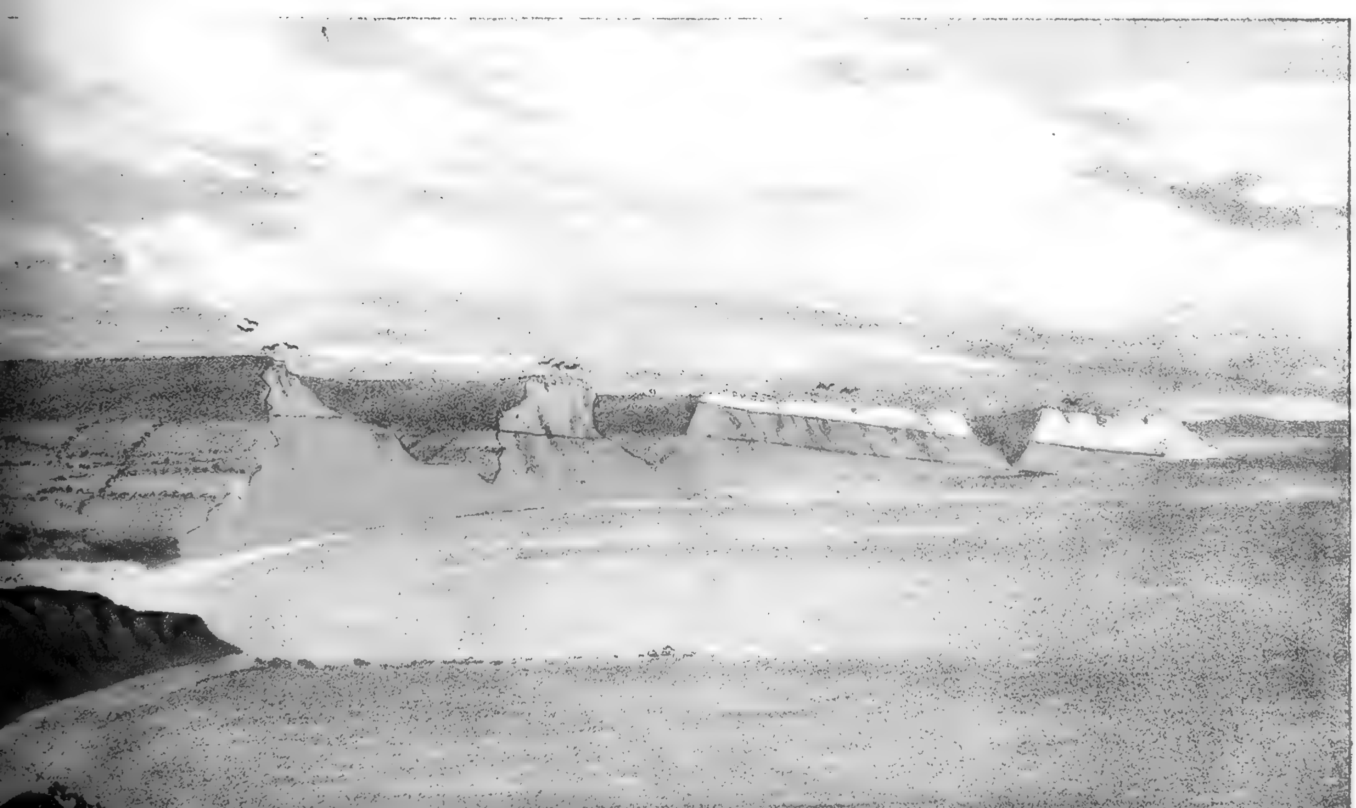
Beds of Chalk Flints.

Printe



Regis, to the Isle of Portland.

Portland Island.
Abbotsbury Castle.
Burton Cliff.
Bridport Harbour
Down Cliffs
Golden Cap
Shorne Cliff
Valley of Charmouth.
Black Ven.



J.D. Harding, Lithog.

om Sidmouth to Beerhead.

andel.

Brandscombe Cliffs.
Little Comb Hill.
Dunscombe Hill.
Salcombe Hill.
Valley of Sidmouth.
Peak Hill.

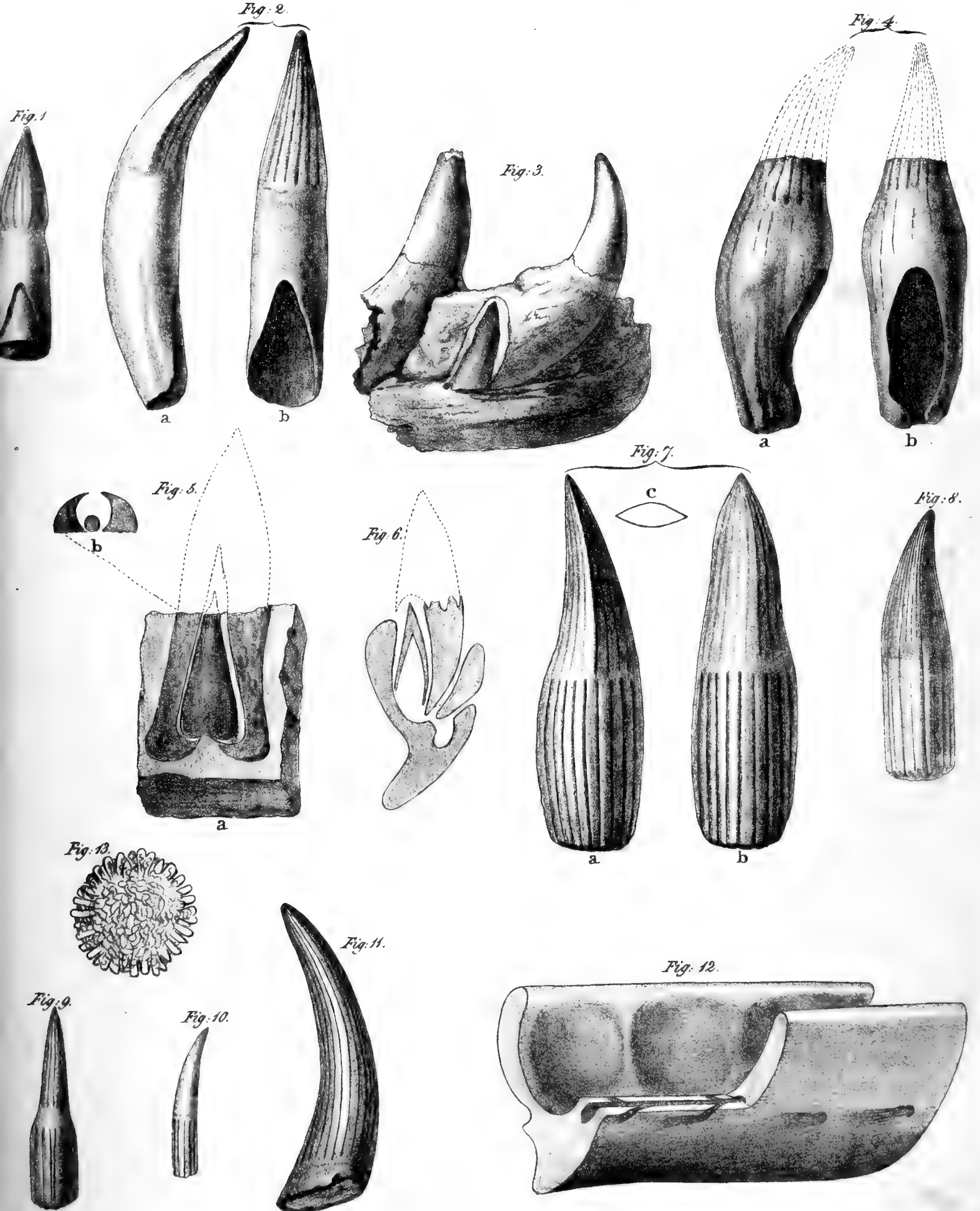


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Fig: 1.

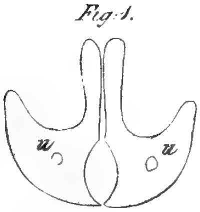


Fig: 2.

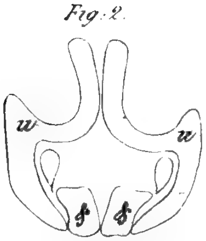
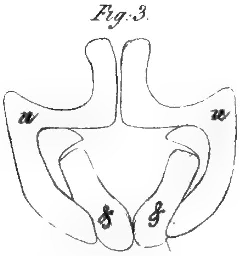


Fig: 3.



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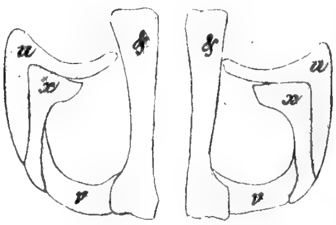


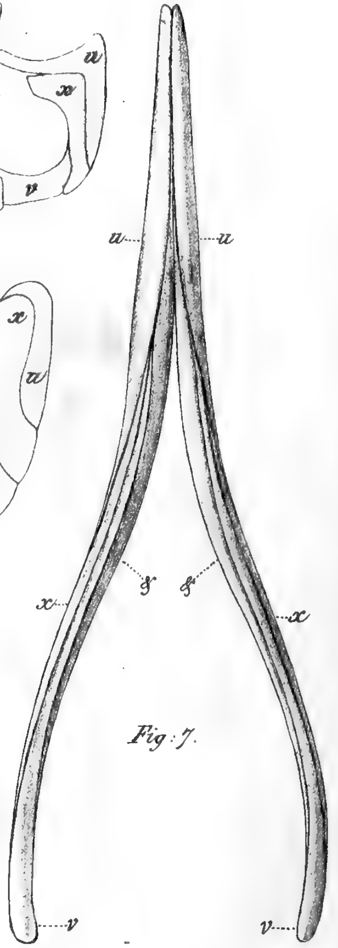


Fig: 7.

Fig 6.

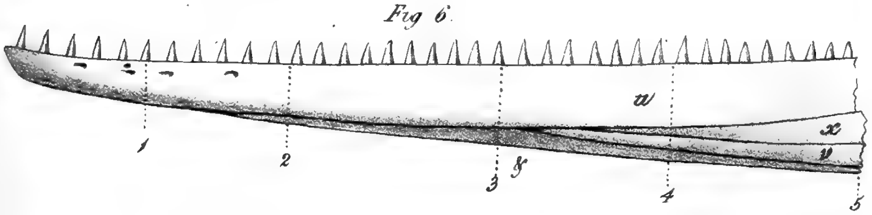


Fig: 5.

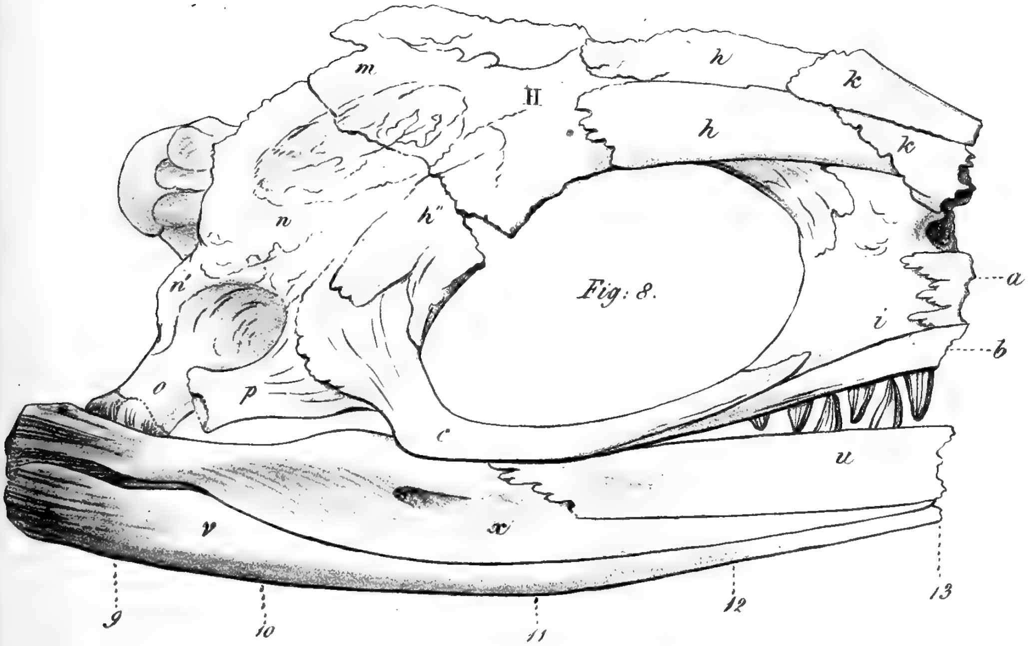


Fig: 8.

Fig: 9.

Fig: 10.

Fig: 11.

Fig: 12.

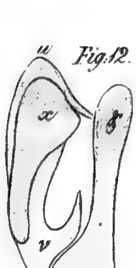


Fig: 13.

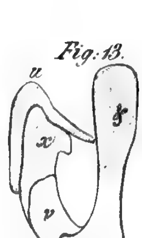
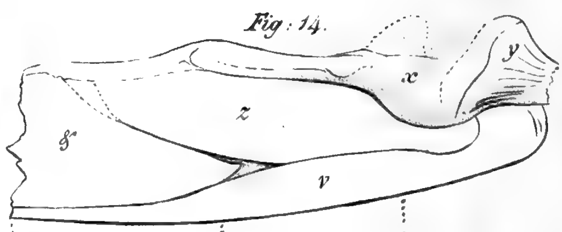


Fig: 14.



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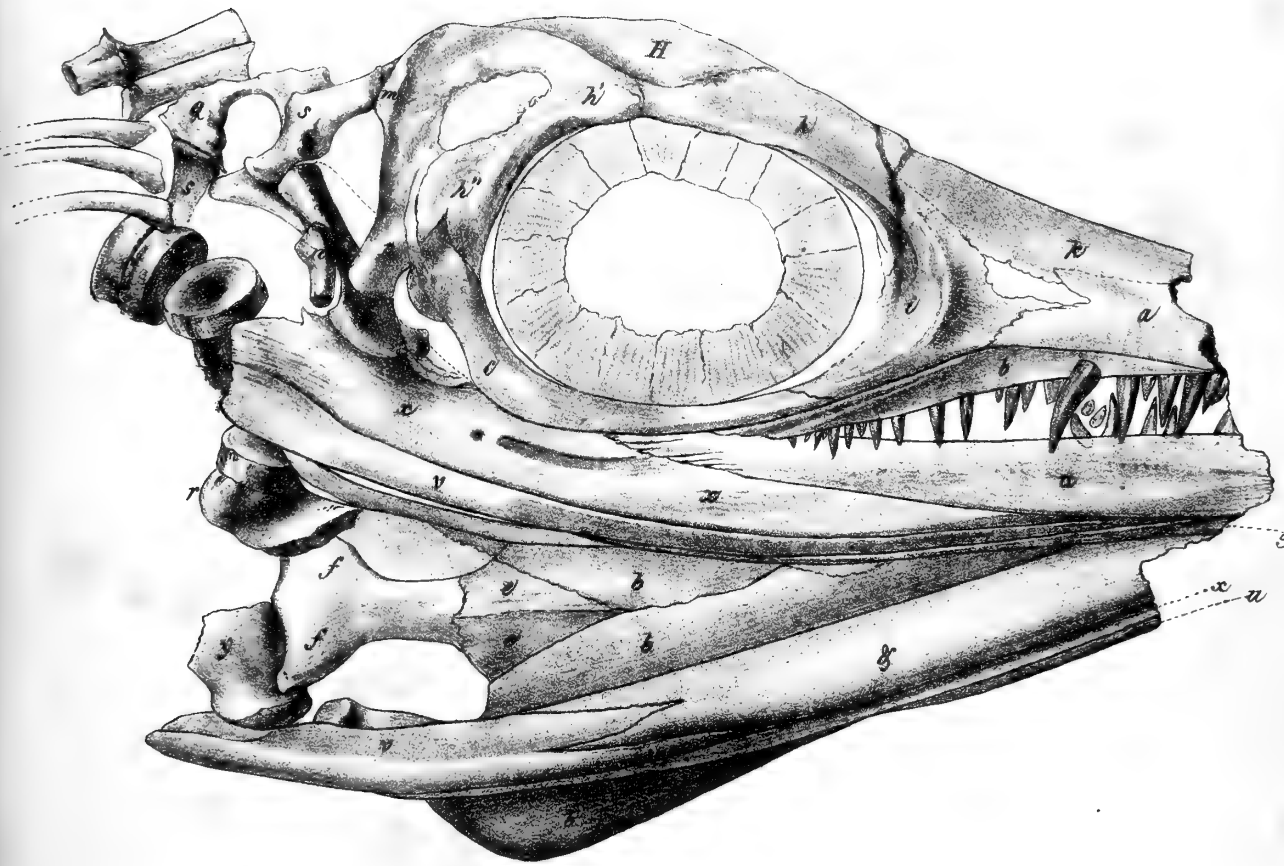

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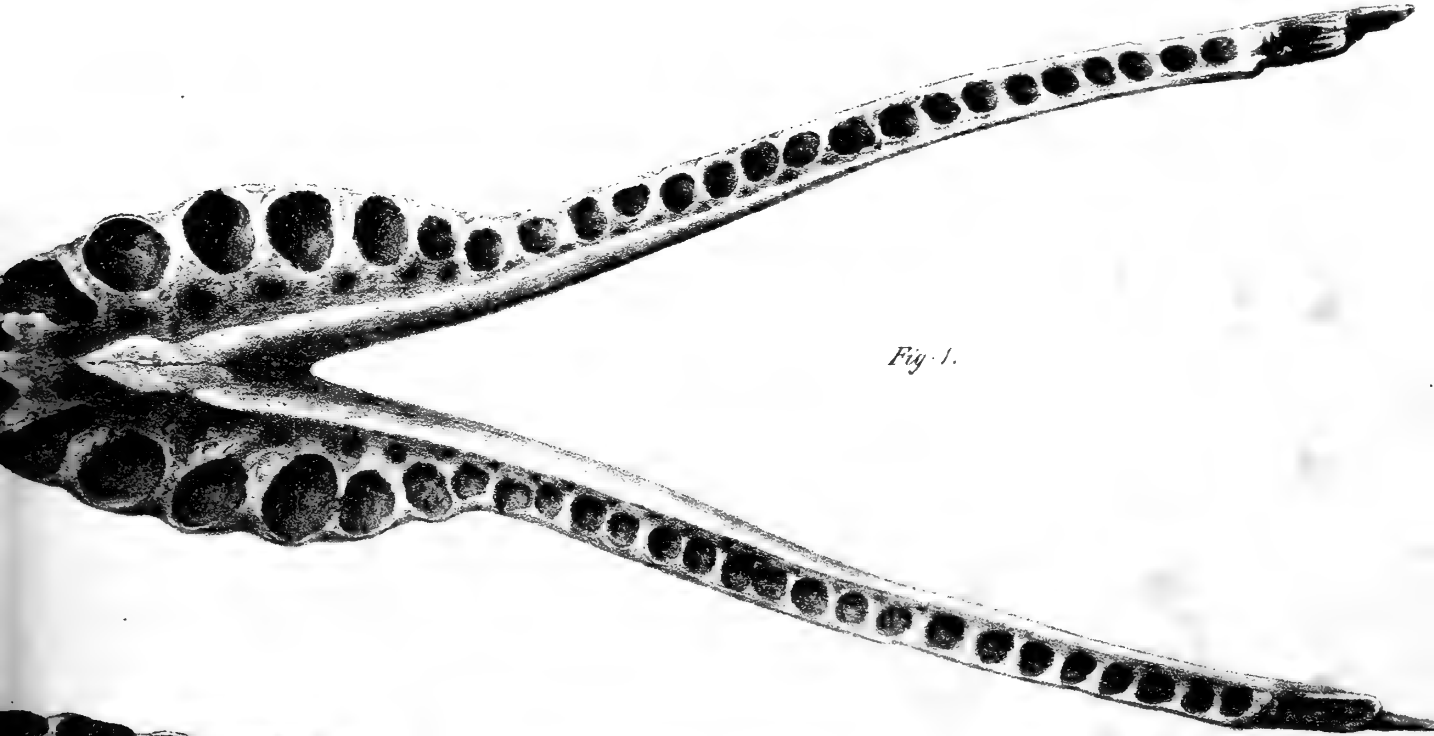

Fig. 1.

Fig. 2.

Fig. 3.

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Fig: 1.

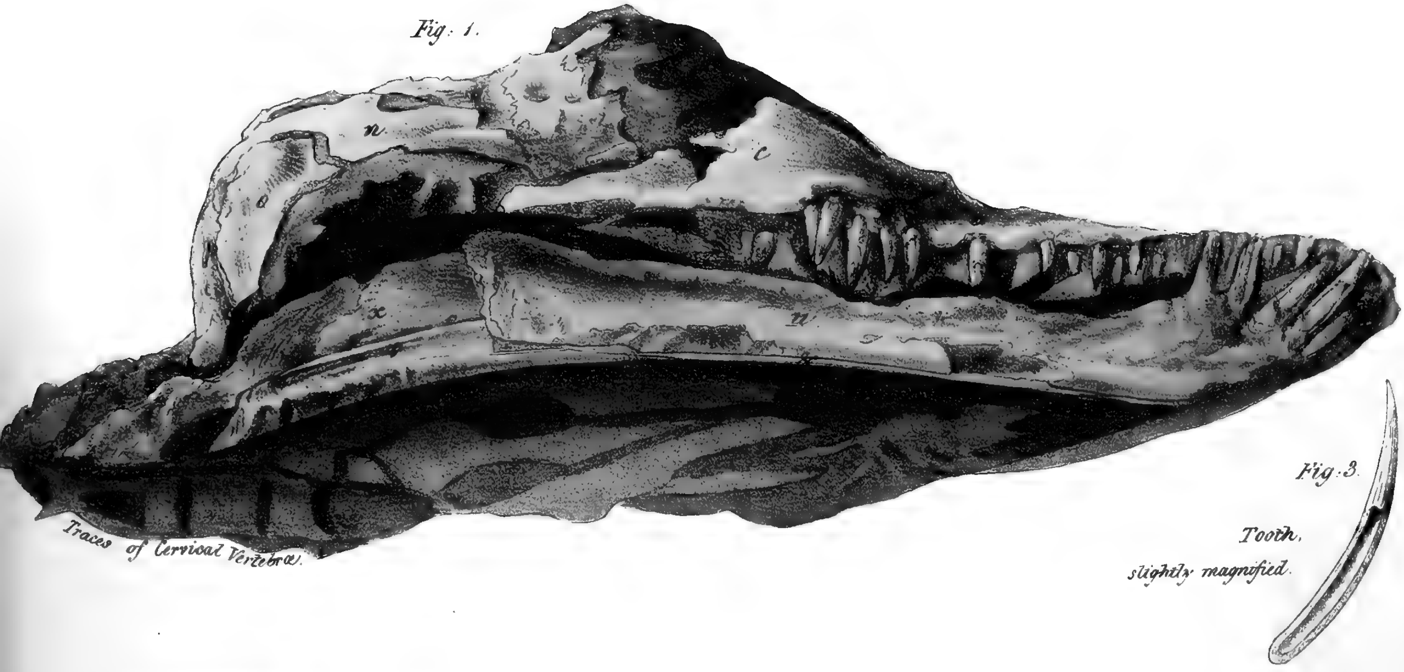
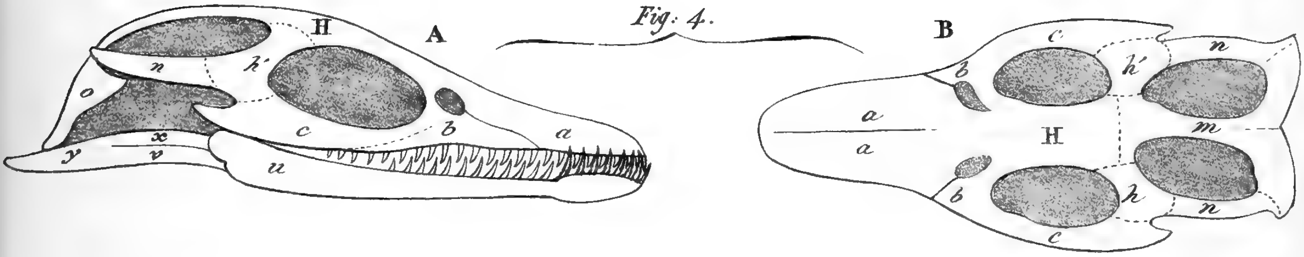


Fig: 3.

Tooth, slightly magnified.

Fig: 4.



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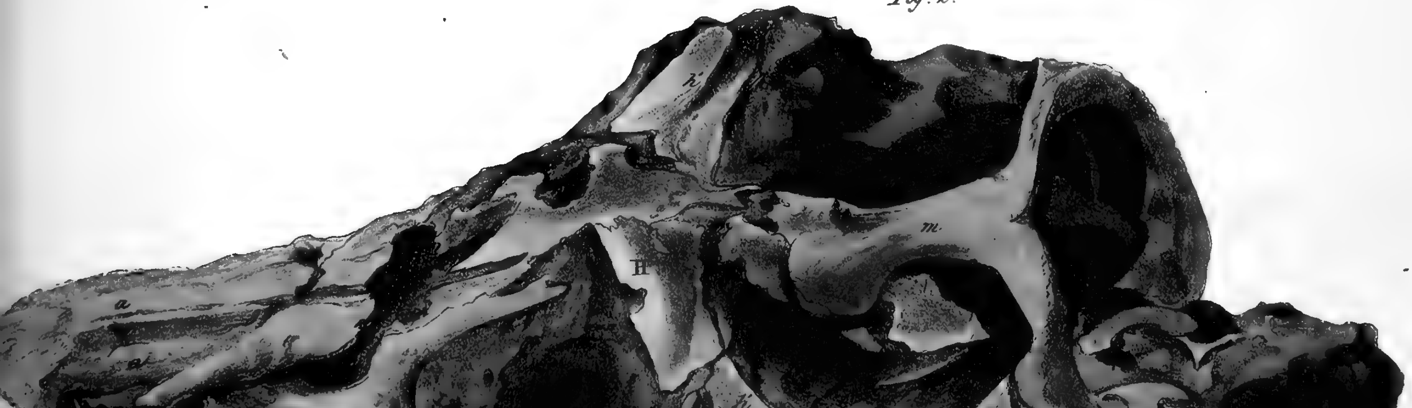


ebster del. *Printed by C. Hullmandel* *G. Scharf Lithog.*

Fig: 1.

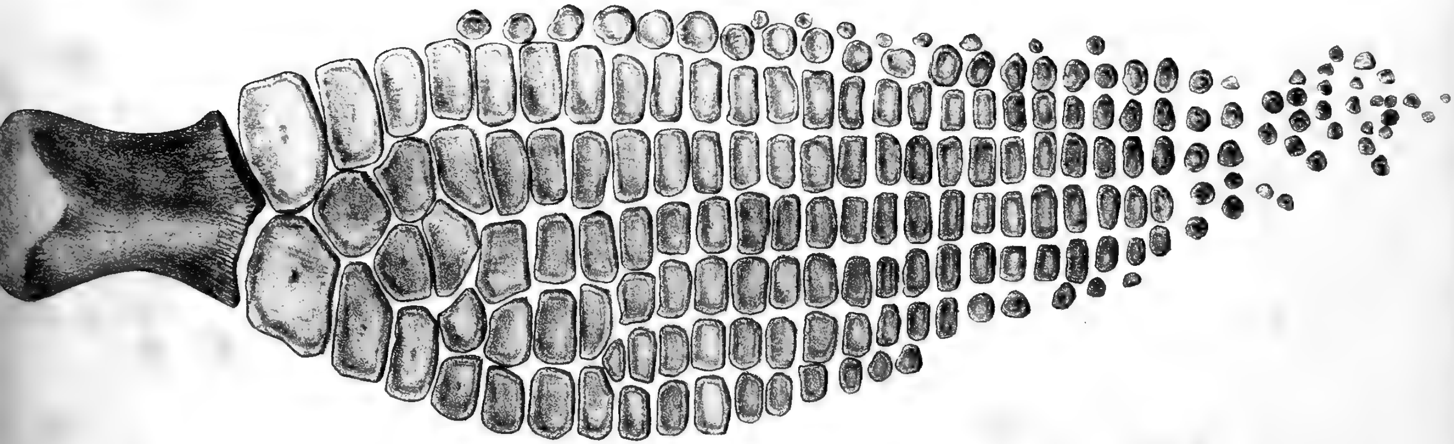
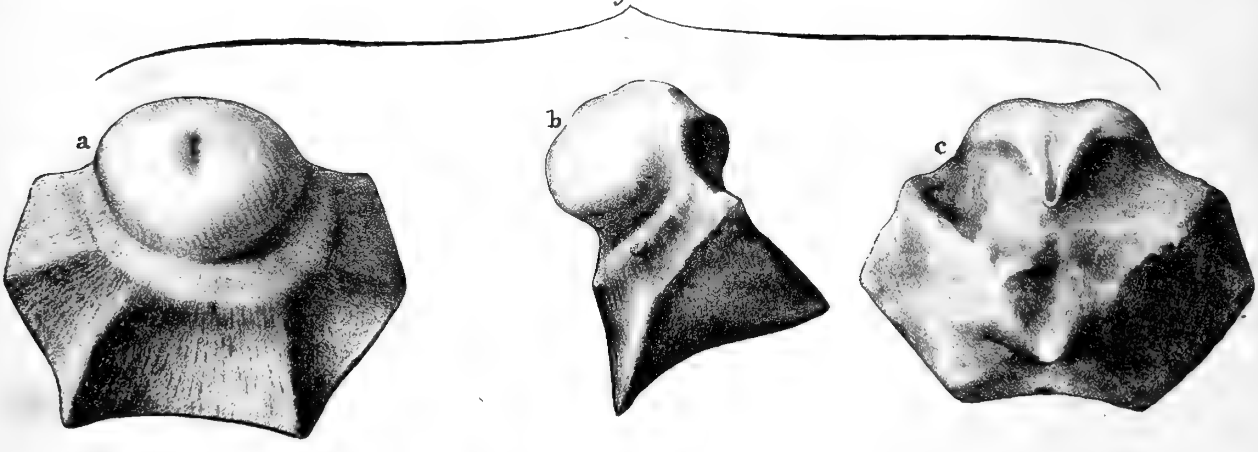


Fig: 2.



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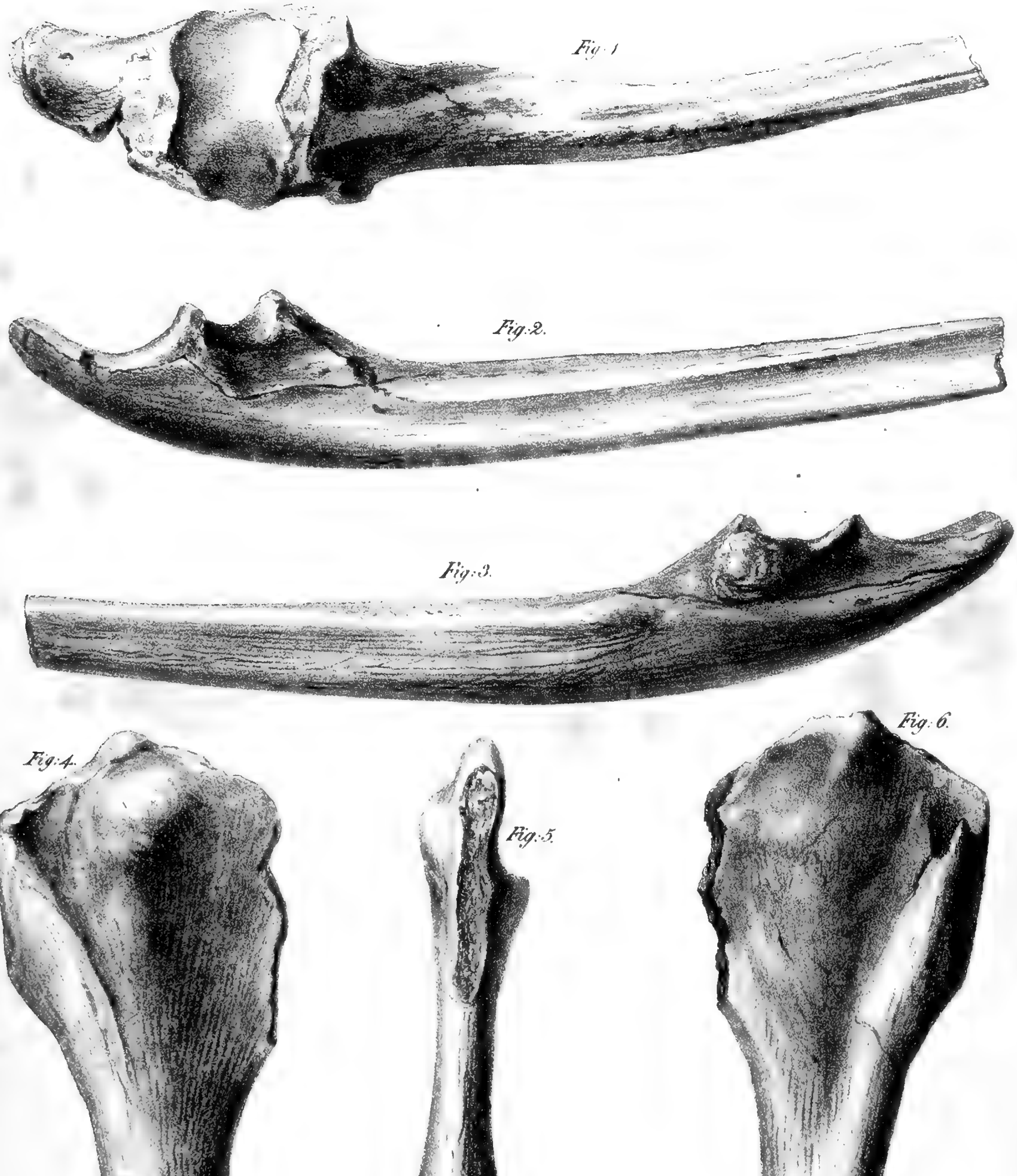
G: Scharf Lithog:



H. T. De la Beche del. Printed by C. Hullmandel. G. Scharf Lithog.

Fig. 1.

Fig 2.

Fig: 3.

Fig: 4.

Fig: 5.

Fig: 6.

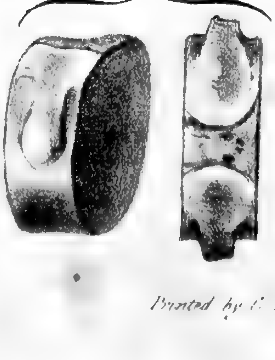


Fig: 7.

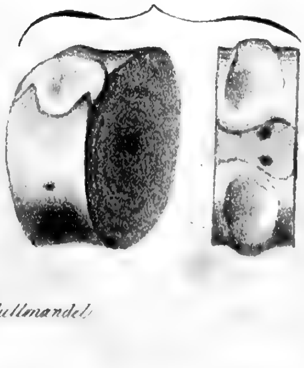


Fig: 8.

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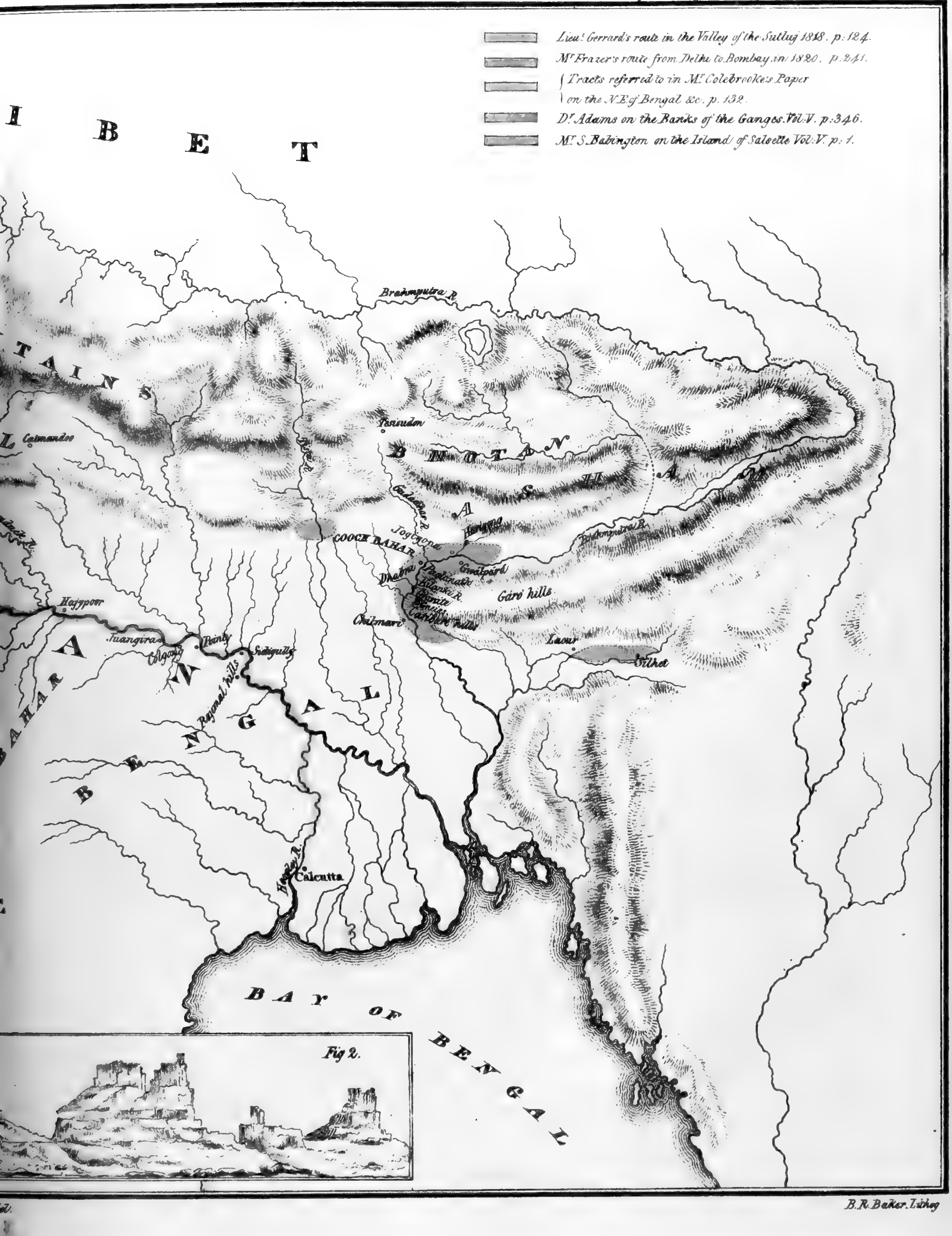

B.R. Baker. Lithog

TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY,

ESTABLISHED NOVEMBER 13, 1807.

SECOND SERIES.

VOLUME I.

PART THE SECOND.

Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant.

Novum Organum, Præfatio.

LONDON:

PRINTED BY RICHARD TAYLOR, SHOE LANE.

SOLD AT THE HOUSE OF THE GEOLOGICAL SOCIETY,
No. 20, BEDFORD STREET, COVENT GARDEN.

1824.

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OF THE

GEOLOGICAL SOCIETY,

ESTABLISHED NOVEMBER 13, 1807.

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NOTICE.

The Council of the Geological Society have recently taken upon themselves the charge and management of the publication of their Transactions, for the purpose of reducing the price, and thereby promoting the diffusion of Geological information. With this view they have adopted a page more full than that of the preceding volumes, and have employed Lithographic Plates instead of Engravings on Copper, wherever the substitution could be effected without injury to the correct illustration of the subjects represented.

As the Transactions of the Geological Society will thus assume a form in some measure new, the Council, for the convenience of purchasers, have determined to commence a New Series of volumes;—that now published being Volume I. Second Series.

London,
July 3, 1822.

ERRATA.

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343	6 from bottom,	quarter,	quarter ;
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409	3	James Fraser, Esq.	James B. Fraser, Esq.
Plate VI.	fig. 1	Dapœdium,	Dapedium.
		tumulated	lunulated
319	7	No. 2 occupies	No. 3 occupies
330	25	the sandstone	the old red sandstone
331	14	Buteley	Berkeley
336	15	transition trap	transition strata
339	30	Sidney	Lidney
345	16	productilites	productites
347	27	felicites	filicites
352	last line	Townhope	Fownhope
365	12	Cherton	Chewton
366	16 and 25	Brackley	Brockley

Plate XXXIX. In the index to the colours, the slate clay (*e*) ought to stand between the carboniferous limestone and the old red sandstone.

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XIV.—*Notes on the Geography and Geology of Lake Huron.*

BY JOHN J. BIGSBY, M.D., F.L.S., M.G.S.,

MEMBER OF THE MEDICO-CHIRURGICAL SOCIETY OF LONDON, HONORARY MEMBER OF THE AMERICAN GEOLOGICAL SOCIETY.

[Read Feb. 21, March 7 and 21, 1823.]

SECT. I. GEOGRAPHICAL SKETCH OF LAKE HURON.

LAKE HURON is the third from the Atlantic Ocean of the great chain of lakes, which occupy the four *plateaux* of the upper part of the valley of the St. Lawrence. It receives the waters of Lake Superior by the Straits of St. Mary, the small lake George, and, finally, by a series of basins and currents; the whole connecting channel being about 39 miles long. It discharges into Lake Erie* by the river St. Clair, Lake St. Clair, and the Detroit River, 26, 25, and 24 miles long, respectively.

Lakes Huron and Michigan are parts of the same body of water, being separated only by the strait of Michilimackinac. Their magnitude entitles them to the denomination of independent lakes †.

The country to the north and north-east of Lake Huron is sterile, rocky, and uneven, full of morasses, creeks, and ponds. It is always hilly, but seldom rises more than 500 feet above the level of the lake; and then in ridges, rarely in cliffs. The higher grounds are naked rocks, with pine and birch springing up in their fissures; while the borders of the marshes and streams (often of a clayey soil mixed with decayed vegetables) produce a profusion of willows, poplars, shrubs, and long grass.

In these desolate regions, scanty tribes of Indians exist by the chase, disposing of their furs to the wandering traders who visit them from Lower Canada.

The tract bordering the southern shore of this lake, and that also which lies between Lake Michigan and the waters of St. Clair and Detroit, is highly fertile. It is low and undulating, with frequent swamps and small lakes,

* Lake Michigan has no outlet but by the St. Clair: when, however, the waters exceed their usual level by a few feet, a communication takes place with the Mississipi by the Illinois river.

† Mr. Hutchins, late geographer to the United States, calculated Lake Huron to cover 5,009,920 acres, and assigned to Michigan more than double that surface.

and showing occasional traces of limestone and sandstone. The mountains delineated on some of the maps of this district are purely imaginary. Among its forest trees are the oak (white and black), ash, walnut, elm, poplar, maple, and various pines. The magnificent nation of Ottawas at L'Arbre Croche, and the Indians on the river Saguina, have long raised excellent vegetables.

The country on the south-east or Canadian shore, from the St. Clair to Cabot's Head, is, on the south, low and damp, with extensive pineries; but northerly it becomes stony and rugged, and its rivers are rapid. It is little known.

The height of Lake Huron above the sea has not been ascertained with accuracy, but may, without great error, be stated at 590 feet. The Commissioners for constructing the western canal in the State of New York, estimated Lake Erie to be 560 feet above tide-water in the River Hudson.—Mr. Schoolcraft, who accompanied Governor Cass in 1820 to the supposed copper mines in Lake Superior, gives 29 feet as the difference in elevation between Lakes Huron and Erie,—which must be near the truth *.

The shape of Lake Huron is so extremely irregular as only to be learnt from the accompanying map. Tracing its main shores loosely with a compass, and omitting the lesser curvatures, its circumference is found to amount to nearly a thousand miles.

The distinguishing feature of this lake is its intersection by the Manitouline chain of islands, which stretches E.S.E. from the promontory of the True Detour, and in longitude 82° approaches within two miles of the northern main land, the strait being nearly filled by an islet. The chain then suddenly trends south-east to Cabot's Head.

Of the three portions into which the lake is divided by the Manitouline chain, the two northern are full of shoals and islands, and that to the north-west is comparatively narrow. The southern division is by much the largest, and is deep, broad, and of free navigation.

Besides the Manitouline chain, and these three principal divisions of the lake, the other points in the geography of Lake Huron demanding particular notice are, the island of St. Joseph lately assigned to Great Britain, Michilimackinac and its vicinity and the Gulf of Saguina.

I have twice visited (in the years 1819 and 1820) the islands of St. Joseph and Michilimackinac; and on my second visit passed three months in their vicinity. In 1819 I descended the French river from Lake Nipissing to Lake

* One-third of the distance is horizontal; straight and tolerably unobstructed rivers occupy the remainder.

Huron, and coasted in a canoe the north main of the latter lake to the Falls of St. Mary. I have been several times on the south coast, and off the Gulf of Saguina. The rest of the lake I know only from the communications of my friends.

The accompanying Map is a reduced copy, with additions, of one of four times the size, compiled by David Thompson Esq. British Astronomer under the 6th and 7th Articles of the Treaty of Ghent, from surveys made by himself, and by Captain Owen, R.N., and from a map of the lake by Mr. Smith, late Surveyor General of Canada. Mr. Thompson, assisted by the American Astronomer Mr. Bird, and party, himself surveyed the north-western arm of the lake and the Manitouline Isles as far east as the river Missasaga and the western end of the Grand Manitou. He also determined the position of the False and True Presquisles, Point aux Barques, the commencement of the River St. Clair, Cape Hurd, the fourth Manitou, Point Colles, and the Hill Islands. Captain Owen's survey comprehends Cabot's Head and its vicinity.

I have added the Georgian Bay and the Straits of Michilimackinac from Purdy's map of Cabotia, and part of Lake George from my own knowledge. I have omitted many islands on the north shore, between the French and Missasaga rivers, from their positions not being yet determined. Mr. Smith's map is only to be trusted in a very general way; the printed maps of the Lake are very erroneous.

I shall now describe those parts of Lake Huron which have been just enumerated.

The appellation of "Manitouline" or "Sacred" Isles is first observed in Lake Huron; and thence westwards is met with in Superior, Michigan, and the vast and numerous lakes of the interior.

The islands of that name in Lake Huron are four in number, Drummond, the Little, the Grand, and the Fourth Manitou, exclusive of the Isle of Coves, and the other fragments of the great ridge that appears to have been once continuous to Cabot's Head. They form a curving line 125 miles long; the direct distance between the extremes being only 97 miles.

Drummond Island is 24 miles long, and (on the average) 8 miles broad: the greatest breadth being 12, and the least $2\frac{1}{2}$ miles. It ranges nearly east; and at the western end approaches the main of the United States, there forming, with the opposite headland, the strait of the True Detour, the principal commercial route to Lake Superior. The strait is scarcely a mile wide, and, being bounded by two promontories, is of very small extent. The coast of the United States is here flat and woody, with morasses; that of the island is uneven, and loaded with large fragments of rock. The general surface of Drummond is irregular; the higher and middle parts rising to the height of from 200 to 250 feet, and inclining on either side to the water; but often presenting low white precipices in broken lines on the summit or sides of the slopes. The low grounds are swamps, often extensive, and filled with mosses, aquatic plants and decaying timber.

The south coast of the island is broken into small but deep bays, with shoal points; and those on the west containing many islets, one of which has an immense deposit of iron pyrites.

The north coast is distinguished by the magnitude of its bays, and by the groups of islands which crowd the contiguous waters. On one of these, near Drummond, and 8 miles from Collier's Harbour, is the Indian town of Portogannosee, consisting of log-huts and gardens of Indian corn and potatoes. The northern coast is terminated on the East, in the strait called the False Detour, by a calcareous precipice of considerable beauty 500 yards long, and 200—250 feet high. At the top it is a terrace of rock; below it is separated from the lake by a narrow shingle beach. This island produces very fine maple of the bird's-eye and curled kinds, pines, hemlock, cedar, poplar, and birch. Few trees attain great size, as well from the scantiness of the soil as from the frequent conflagrations *.

The point which forms the west end of Drummond is the northern arm of the bay containing Collier's Harbour, the most distant of the British military posts. This harbour is circumscribed to the diameter of half a mile by islets, surrounding the front of the bay, through which islets there are three entrances. It is oval, and possesses good anchorage; but the wind, which brings a vessel to anchor, either altogether prevents her departure, or renders it very difficult; and there are also many reefs in the vicinity.

On an acclivity in front of the harbour stands a village of about 50 wooden houses and huts, with the barracks of the military built of logs on the right. The land around the village is cleared. It is hilly, and is absolutely buried under enormous accumulations of rocky fragments, consisting principally of very white limestone. They are from a few inches to several yards in diameter, and, at this place almost exclusively, contain the nondescript madrepore represented in Pl. 28. Piles of these fragments, by their fissures and interstices invested with thick moss, render the woods quite impassable.

* These fires originate in lightning, or in the carelessness of Indians, and spread from the great quantity of dry timber and leaves with which the ground is strown. They are frequently so extensive and numerous in summer, as to cloud the atmosphere as with a fog. In the night I have seen three or four large tracts red with a smouldering flame, which, as the trees fall, shoots up in fiery columns far into the sky. The noise of the falling of the trees, and the crackling of the timber, is heard at a great distance.

Opposite the centre of the harbour, and behind the village, at a short distance, is an eminence called Blockhouse Hill, which has the form of an embankment, and is composed of sand and rolled pebbles of various rocks.

There is a gentle ascent from the water's edge to the distance of from 300 to 500 yards. A sudden rise of from 20 to 30 feet then takes place at an angle of 65°, forming the bluff in question, which presents to the west a front 150 yards broad, and then retires, widening on either side, until after some yards it is lost in the generally increased height of the ground. Its base is strown with masses of primitive rocks, and its summit is covered with large slabs of the limestone of the island. Nothing can be more harsh and desolate than the aspect of this station on a near inspection. The village itself is encumbered with debris of rocks, so numerous and sharp-edged as to render walking very difficult. The sterile vicinity is bristled with black stumps and half-consumed pines *.

At the bottom of a large *cul-de-sac* in Collier's Harbour, a narrow stream, which falls from a small height in the Lake, communicates with a chain of small lakes running into the interior of the island. The first of these is a mile long, half a mile broad, and is surrounded by a dense forest, growing among reeds and rushes. To the east of this is an opening leading to a second lake, and that to a third.

Drummond Island is separated from the Little Manitou by the False Detour, a strait so called from its being frequently mistaken for the True. It is from 8 to 10 miles long, and its greatest breadth is from 3 to 6 miles. Its depth in the middle is seldom less than from 30 to 40 fathoms. As you enter it from the south the opening is spacious and bold, with three fine capes on the west, and one on the east. On the angle of Little Manitou is a shoal, with a mass of white rocks in the centre: a short way within the strait, close to the last island, are three low marshy isles crowded together. At the northern outlet the shores are very rounded, with precipices on the west, and woody steeps to the east. In front is the open lake, studded with a few islets in pairs, and terminated in the distance by the mis-shapen hills of the northern main. On the north-west is a blue waving line of the heights of St. Joseph, and on the north-east the looming of the isles about La Cloche is just visible.

Little Manitou observes an eastern course. It is of a rounded form, with a diameter of 7 or 8 miles. Its features are the same as those of Drummond, but it is perhaps higher. Frequent conflagrations have destroyed almost all

* In 1820 this post only escaped destruction, by a fire spreading from the woods, through the great exertions of the inhabitants and a body of Indians.

the well-grown timber (still leaving some uncommonly large hemlock), and have exposed the ascending sides of the island in many places. The shores are loaded with successive banks or stairs of small debris, and have here and there terraces of limestone *in situ*. Mounting upwards, the ground is rugged with protruding strata and rolled primitive masses; and not unfrequently intersected by short ledges, which often crown the greatest heights, affording a table-land of small extent, and better wooded than the surface below, which is only sprinkled with very young poplar-, birch-, and cherry-trees.

There is a convenient harbour on the north side in the second bay from the Third Detour. It is a deep oblong indentation in this bay, and itself contains an inner cove. It is a quarter of a mile broad. The ship entrance is narrowed to a few yards by a shoal that runs from the east angle two-thirds across.

Within this bar a vessel may ride with from 9 to 12 feet water in tolerably roomy anchorage, the depth decreasing gradually towards the bottom of the indentation.

The third detour, between Little and Grand Manitou, is 8 miles long by 4 broad, with high shores, and clear at both outlets. Off the south-east end of the Little Manitou is a very extensive but easily distinguished shoal.

The Grand Manitou may be estimated at 75 miles long, and 8 miles broad on the average. About its middle it is 25 miles broad, and at two places to the west of the widest part, the shores are so deeply indented as nearly to divide the island, only narrow morasses intervening between opposite bays.

The general characters of the Grand Manitou are the same as those of Drummond, but on a larger scale. It is higher, abounds more in precipices, and is more rugged throughout*. At the western end it is of more majestic features than any of the country which I have seen in other parts of Lake Huron. At the north end of the Third Detour, its shores are lined with ranges of shingle, supported behind by an ascending country of woods.—Toward the centre of this strait, ledges and low precipices begin to appear along the beach, and soon rise to the height of 250 feet, crowned with cedar and pine. These ledges either rise perpendicularly, or are formed of enormous piles of displaced masses, from 7 to 10 yards in diameter, sloping at a high angle. These blocks advance into the water, and afford a hazardous path over their slippery sides, under arches and through winding passages. Within half a mile of the south-east angle of the Detour, a bluff precipice 40 feet high protrudes into the water, skirted by very large cubic masses of rock. Of such masses, resting precisely on one another, the bluff itself is

* The above particulars I learnt from my friend and companion, Lieut. John Grant, R.N.; having myself only visited the western end of the island.

composed; so that the summit, with much of the land behind, is a platform of naked rock. Out of these natural terraces, knolls of flowering shrubs and clumps of trees arise. Behind them is the dense gloom of impenetrable woods.

Of the strait which divides the Grand Manitou from the northern main I possess no information further than what has been stated. At a time when the Manitoulines were quite unexplored, I sailed through the strait without distinguishing it from the numerous passes in that labyrinth of islands. It has now undergone two surveys.

The strait which divides the Grand from the Fourth Manitou on the north is only one mile broad; but on the average a league. It has been very seldom visited.

Of the Fourth Manitou little is known. It is narrow, and of about one third the size of the Little Manitou; its long diameter crossing the direction of the Manitouline chain. The shores are much indented, and afford a very convenient harbour on its eastern side, which was used in 1821 by His Majesty's schooner Confiance, Lieut. Grant.

The fifth and easternmost strait between the Fourth Manitou and Cabot's Head is 14 miles broad, and contains many shoals and islands, of which the largest is appropriately named the Isle of Coves.

The island on which are those singularly shaped rocks called the Flower-pots, has long attracted notice. Accounts differ respecting its precise situation; but it lies probably about 6 miles S.S.E. of the Fourth Manitou. The Flower-pots are several insulated rocks, the greatest 47 feet high, consisting of large tabular masses, placed horizontally one upon the other, and broad at the summit, but narrow below. They stand on a floor of rock projecting into the lake from the lofty island which bears their name.

Cabot's Head, a singular headland, is evidently a continuation of the Manitouline ridge. It lies 144 miles almost due north of St. Clair. It faces north for about 25 miles, and then passes off to the south and east. It consists of much indented limestone bluffs, rising occasionally to the height of 300 feet, and skirted by numerous reefs and islets. On the western side of the headland, and to the south of it, the first 64 miles of coast display a range of calcareous precipices. A little to the north-east of Cape Hurd, the western extremity of Cabot's Head, one of the curvatures of the cliff forms a *cul-de-sac,* 800 yards long and 80 broad, having 7 fathoms water. It thus affords an useful haven in this intricate part of the lake.

In addition to these remarks on the southern extremity of the Manitouline chain, I have only to notice its generally increased elevation in this part of the main, and in the neighbouring isles.

Having completed my geographical observations on the Manitoulines, I shall now proceed to describe the three principal divisions of Lake Huron.

The north-west arm of Lake Huron, which communicates with Lake Superior, is of an oblong shape, the two longer sides at their western extremities converging towards the north. It contains about 400 square miles, and is crowded with islands of all magnitudes. The principal of these is St. Joseph. It is 65 miles in circumference; and, together with the large Sugar Island, is wedged into the end of the channel from Lake Superior, scarcely allowing at the narrowest points the breadth of a mile to the sum of the three outlets from Lake George.

St. Joseph is somewhat triangular in its form, its north and east sides meeting almost at right angles.

Although an undulating ridge called the Highlands of St. Joseph, about 500 feet high, is found throughout the island at the distance of a few miles from the lake, yet the surface is not so broken as that of the Manitoulines; and the whole is better wooded. It has few or no precipices, but it is singularly loaded with the debris of foreign rocks. Its southern point, a picturesque cleared mound, once the site of a military post called Fort St. Joseph, and lately occupied by the British garrison at Collier's Harbour for pasturage, is only six miles from Drummond. The north-west point of the island is 26 miles from this mound, in long. 84° and lat. 46° 18′; and the eastern angle lies about 18 miles north-north-east of it by the ship's course.

The waters on the north, west, and south-west of St. Joseph have received distinct appellations. That on the south, bounded also by Drummond, is a large irregularly shaped archipelago, containing sixty-one islands and many shoals.

The part of Lake Huron included between the north-east shore of St. Joseph and the contiguous main, is called the Channel of Pelletau, from the name of a solitary Canadian residing on an isle at its east end. Except towards the western extremity, this channel is almost a clear sheet of water, from 10 to 12 miles long, 6 miles broad at the east end, and about a mile and a half at the west. On the two sides of this channel the aspect of the country is very different. On the south, the verdant acclivities of St. Joseph are trending to the north-west in two large bays. On the north are the black and denuded fastnesses of the main land; an assemblage of greenstone mounds, swamps, and ponds; with the margin of the lake fringed with reefs and rocky islets.

Near the west end, Pelletau's Channel widens into an expanse of 25 square miles, and becomes full of islands, three of which are much larger than the rest; and of these the largest is high, compact, and woody, and nearly blocks up the lower entrance of the Narrows. The two others are at the north-east angle of this dilatation, close to the main, with which they form an admirable haven, lately selected by the Governor-general of British North America as a military position by the name of Portlock Harbour. It is remarkable for fine scenery. While in Pelletau's Channel, as you approach the harbour, at the distance of a mile or so, there is perceived an opening or break in a high country, expanding as it is neared, and finally disclosing an extensive haven interspersed with rocky islets, and girt by heights starting forth in a series of woody or rocky capes: the whole is supported in the rear by three ridges of hills covered with poplar, birch, and half-consumed pines.

The Narrows or Strait, at the upper end of the Channel of Pelletau, is one of the three outlets from Lake George which may be considered as forming the north-west limits of Lake Huron, since it there begins to be the seat of currents, and of contracted dimensions. This strait is formed by the approach of St. Joseph to within two thirds of a mile of the northern main. This is the extreme contraction, and occurs at the western end; at the east the width is almost a mile and a half. The length of the strait is 2 miles. The main is a line of dark and lofty precipices. This part of St. Joseph is marshy.

The small space constituting the Narrows contains eighteen islands; those near the main partaking of its sterile and forbidding character, and sometimes being divided from each other by mural passages only a few feet across. From the summit of the adjoining main is presented a truly scenic and striking combination of high and sombre rocks, scantily clad with pine, and overshadowing a labyrinth of waters. As the islets approach St. Joseph, they become low and woody, with marshy coves and shallow currents in their intervals.

A current prevails in the Narrows, but weak and inconstant. It is strong at their western aperture, and is perhaps sensible throughout the basin into which it leads.

The Narrows have considerable but various depth. At the east end, near an excellent harbour, the lead indicated a depth of 42 feet, and being removed a yard or so gave 96 feet.

The second outlet from the Rapids to Lake Superior is the strait between St. Joseph and Sugar Island, called the Middle Passage, which terminates at the lower end in Muddy Lake. It is from 8 to 10 miles long, having nearly a southerly direction, and about 1 mile broad; but it is contracted to one fourth of that width at the lower end. The current is seldom half a mile per hour.

The Lesser or south-western Nibish Rapid completes the number of the channels that lead to Lake Superior. It is contained by the western shore of Sugar Island, and the southern or United States main. It occasionally expands into basins, but is usually very narrow. About three miles to the west of Muddy Lake, it is not more than $\frac{3}{4}$ of a mile broad, and has six or seven islets crowded in it. It is very shallow.

Muddy Lake, bounding the south-west side of St. Joseph, is a fine sheet of water, of irregular shape, 17 miles long, and varying from 2 to 7 in breadth. It has received its name from the nature of its bottom. There is one small isle at the upper end, and a large one called Isle à la Crosse at the bottom, with two or three others. Its shores are deep embayments ending in grassy marshes, especially on the south-east side. There are several shoals; one, having $6\frac{1}{2}$ feet water, at the foot of the Middle Passage; another somewhat to the south-west, and some dry rocks at the lower end of the lake. Sugar Island and George Island, the former 20, the latter 12 miles long, are the two principal islands west of St. Joseph in the water communication between Lake Huron and Lake Superior. The lower end of Sugar Island constitutes the northern shore of Muddy Lake; that of George Island terminates in the Middle Nibish, and the north-west Nibish rapids.

The Nibish rapids, which are 4 miles long, or more, are separated from one another by these two islands. The lesser or south-western rapid has been already noticed as flowing between Sugar Island and the southern main. The middle Nibish, distant one mile from the north-western point of St. Joseph, divides George Island from Sugar Island, and empties itself principally through the middle passage. The waters of the north-west and north or Little Nibish pass off on the northern side of St. Joseph by two basins of comparatively calm water, 3 and 5 miles long respectively, divided by an imperfect barrier of islands; the lower basin discharging into the Narrows of Pelletau.

The Nibish rapids terminate upwards in a large basin, 8 miles long, and 10 or 12 broad, called Lake George, containing, besides the upper portions of Sugar and George Islands, a multitude of smaller ones.

The Straits of St. Mary, which unite Lake George to Lake Superior, are 17 miles long, and from $\frac{3}{4}$ to $\frac{1}{2}$ of a mile broad, and have very violent rapids at a narrow marshy spot about 2 miles above Lake George.

The Michilimackinac, or south-west arm of Lake Huron, has never been examined, or only by the military engineers of the United States, whose labours have not hitherto been communicated to the public. It is connected with Lake Michigan by the strait of Michilimackinac, from 8 to 11 miles wide, and of insignificant length, as being formed only by two opposite promontories.

Its south side presents no peculiarities, except a peninsula, called False

Presquisle, 9 miles from the island of Michilimackinac. On its north lies Isle Bois-blanc.

The north side is merely a succession of shingled points and reaches, with a thickly wooded and marshy interior, traversed by several streams.

The island of Michilimackinac is midway from either main, close to the strait of that name. It is 42 miles west of Drummond. It is a long oval about 9 miles in circumference. The ends are broken, crumbling or grassy ridges, while the long sides are lofty precipices declining at each extremity, separated from the lake by rather broad beaches, and picturesquely clothed with maple, cedar and vines, except where projecting rocks show their white and craggy peaks above the foliage.

The view into Lake Michigan from the Indian path which winds among the coppice on the top of the south-west cliff, is particularly pleasing. The land, at first closing on the water at the pretty hamlet of St. Ignace and its corresponding headland, at once dilates into a spacious sound with curving shores and woody capes, and is interspersed in the extreme distance by clusters of islands.

The cliffs of this island frequently break into shallow caves, which actually perforate a projecting point near the south-east angle. Its height (150 feet), its whiteness contrasted with the dark shrubs, and the blue light streaming through the aperture, afford a fine composition for the painter.

Excepting three small farms, little of the interior is cultivated: the heavy timber has been felled; and time has replaced it by flourishing underwood. The surface is high and uneven, often marshy.

The town, consisting of from 100 to 120 decent wooden houses, is at the southern end of the island, on the beach, under a crumbling ridge, on the edge of whose summit is placed a small white fort.

On the south coast of Lake Huron, at about one third of the distance from Michilimackinac to the Gulf of Saguina, there is an excellent harbour formed chiefly by a peninsula. It is called Presquisle; and is in lat. 45° 20′ 39″; long. 83° 30′ 13″.

Little or no information is to be found in the writings of travellers respecting the Gulf of Saguina. Batteaux, trading between Detroit and the lakes of the west, pass down every summer as far as Traverse Island to avoid crossing its boisterous mouth, where they would lose sight of land.

This gulf and Thunder Bay are much larger than they are represented in Smith's or Purdy's map, and also in the one accompanying these notes; but as I have no documents for laying down this part of the lake with accuracy, I have copied from preceding authors.

Thunder Bay Islands and Middle Islands are flat, calcareous, and well wooded. The lake, as I am informed by Major Delafield, for three quarters of a mile east of Middle Island has only four feet water; indeed all the secondary islands of Lake Huron are surrounded by extensive spits and shallows.

The shore from Point aux Barques to the river St. Clair forms a tolerably straight line of beach with now and then a low cliff of clay. About midway, a large block of white limestone rises from the waters of the lake, well known to *voyageurs* by the name of Rocheblanche.

In describing the Manitouline Isles, I have already noticed Cabot's Head, and the coast in its vicinity.

I have collected very few materials for the geography of the Georgian Bay. It is now under survey by Lieut. Bayfield R.N., assisted by Midsh. Collins. They report it to be crowded with islands and rocks.

Penetanguishene*, the British naval station in Lake Huron, is situated in an inner bay of Gloucester Harbour. It is sheltered, as its name indicates, by hills of sand and rolled blocks; the coast and neighbouring islands being of similar constitution for 30 miles round, but having a primitive base.

It remains now to add a few remarks on the rivers of Lake Huron.

The principal rivers are the Thessalon, Missassaga, French, Severn, St. Clair, and Saguina†. There are multitudes of smaller streams unmarked in the map, which pour a brownish red water into the lake, and several of considerable size to the east-south-east of Cabot's Head.

The river Thessalon flows into a deep bay on the north coast. It is 50 yards wide at its mouth; and in three or four miles becomes a mere creek. I have noticed it because it is usually thought larger.

The river Missassaga at its entrance into the lake is $\frac{1}{2}$ a mile wide, and passes through a large swampy country, apparently alluvial. For five or six miles the breadth rather increases as we proceed upwards. The current, though usually sluggish, is at times rapid. Its borders are covered with long grass and willows. Indians say that its source is a lake of the same name, lying twenty days' journey to the north.

The French River from Lake Nipissing to Lake Huron, an interval of 75 miles, possesses peculiar characters. It less resembles one stream, than a confused assemblage of rivers flowing, with frequent inosculations, among lengthened ridges of rock. Its shores seldom present continuous lines, bounding a

* Long. 79° 35′, lat. 44° 57′.

† There is another large one marked in the map in long. 82° 7′, lat. 46° 10′, or thereabouts. I never heard of it.

compact body of water, but are excavated with deep and narrow bays obscured by high walls of rock and dwarf pines.

Its breadth therefore is variable; sometimes extending more than a league, and occupied by every diversity of island.

Few American prospects exceed in grandeur and singularity those which are here afforded by groups of long and lofty islets, extending in giant rays from a centre into some dark bay, the clear water reflecting their rugged outlines and wild foliage, amid the solemn stillness pervading these solitudes.

Two cataracts occur. By one it leaves Lake Nipissing: the other is 20 miles below, and is called the Recollet. It is about 10 feet high, and is narrow. It is divided into three parts by two fragments of rock. The adjacent red feldspathose eminences, and the black crags in the midst of the foaming waters, beset with living and dead pine, impart great beauty to the scene.

There are many rapids; the most serious of which is that of Brisson, remarkable for its thirteen wooden crosses, commemorative of as many fatal accidents.

The current is always strong; perhaps 2 miles per hour.

The river Severn, about 25 miles long, and issuing from Lake Simcoe, is $1\frac{1}{4}$ mile broad at its mouth near Penetanguishene. It has two falls, and undergoes a total descent of 80 feet from that lake*.

The St. Clair is the only river of discharge possessed by Lakes Michigan, Superior and Huron, which have a surface of $38\frac{1}{2}$ millions of acres, and are fed by numerous rivers many times larger than the St. Clair, and issuing from lakes of great dimensions. The evaporation must consequently be immense. No hygrometric observations have yet been made.

The River St. Clair is 300 yards broad at its commencement. It flows through a luxuriant alluvial country, with an average breadth of 1000 yards. It is 26 miles long; with a straight course and smooth and equable current of about 2 miles per hour. At its head there is a rapid for $\frac{3}{4}$ of a mile at the rate of 5 miles per hour. It enters Lake St. Clair by a multitude of shallow changeable mouths.

The River Saguina (as I am informed by the Rev. Mr. Hudson, missionary to the Saguina Indians,) is 180 yards broad for 24 miles, flowing through a level and heavily timbered district. It then divides itself into three small and very circuitous branches, one of which is called Flint River. The River Saguina is 120 miles from Detroit through the woods, and perhaps 220 by water.

* This calculation places Lake Simcoe more than 400 feet above Lake Ontario, distant 30 miles. The ascent is almost imperceptible, as I am informed.

Its neighbourhood has recently been surveyed, preparatory to sale by the Government of the United States.

Sect. II. ON THE GEOLOGY OF THE COUNTRY BORDERING ON LAKEHURON.

§ 1. ON THE ROCKS *IN SITU*.

I will not apologize for the deficiencies that may be remarked, nor for the inaccuracies that future observation may detect in the following pages. They are in a manner natural to the efforts of a first observer in an unknown, vast, and savage country.

The northern shore of Lake Huron, with its nearest isles, consists principally of the older rocks; the secondary occupy the rest of the lake. The primitive rocks are part of a vast chain, of which the southern portion, extending probably uninterruptedly from the north and east of Lake Winnipeg*, passes thence along the northern shores of Lakes Superior, Huron, and Simcoe, and after forming the granitic barrier of the Thouraud Isles at the outlet of Lake Ontario, spreads itself largely throughout the state of New York, and then joins with the Alleghanies and their southern continuations.

The geology of that part of this primitive chain which borders on Lake Huron is but imperfectly known. I shall give such detached information concerning it as I am possessed of.

The French River flows over a granular gneiss at its source and mouth; and over red and feldspathic gneiss about the falls of the Recollet. Its shivered and dislocated state, its mossy coating, and the astonishing quantity of native debris prevented my ascertaining the direction of the strata, although I landed more than once during my passage down the river.

The low and sandy beaches of the south shore of Lake Nipissing are crowded with mounds of gneiss unmixed with any other rock. The direction, from its great irregularity, I was unable to determine.

The rocks of the north coast, and its contiguous islands east from the French River, consist of gneiss, with occasional mixture of hornblende†.

From the French River westwards to the islands of La Cloche, about 50 miles distant, the lake near the shore is studded with innumerable islets. In the first 20 miles they commonly consist of gneiss, are barren, and surrounded by shoals, and are often, in fact, a heap of ruins. This is particularly the case

* Vide *Geological Transactions*, vol. v. Part II. page 607.

† Communicated to me by Lieut. Grant.

very near the main; but further out in the lake they are loftier, and sometimes girded with a belt of flat ground, richly wooded. This belt was in many instances visibly supported on an horizontal dark slaty rock, which afterwards proved to be shell limestone. The primitive rocks of these islands retained their wonted sterility. Both the islands themselves, and most of the ridges of which they are composed, have a south-west direction; and individual masses of gneiss were observed to dip either vertically or more or less to the south-east;—a coincidence in position with the gneiss of the whole valley of the St. Lawrence, worthy of being remarked.

The Isles of La Cloche form a charming contrast to the bleak hills of the main, in their forests and grassy vales, diversified, like an English park, by clumps of fine trees. Some of them are composed, as I am informed (for I did not see it), of a dark rock, which when struck sounds like a bell.

From La Cloche to the river Missassaga, a distance of 60 miles, is another assemblage of isles; but principally, I believe, within 6 miles of the shore. In the first five leagues from La Cloche, they are woody, except those near the shore, which are barren, and composed of gneiss. Landing here on the main, I found issuing from a morass a round smooth mass (probably a vein), 50 yards broad, of crystalline quartz rock, running south-west, and containing nests of silvery mica and galena. The former in some parts combining with the rock, rendered it fibrous.

Twenty miles from La Cloche, and four from the main, is a chain of five or more short islets, parallel to each other, and having their long diameter to the north. They are composed of genuine granite; and are bare, low, and smooth.

Further to the west, soon after this, a multitude of small sterile islets, loaded with debris, occur for 20 miles along the shore, composed chiefly of hornblende rock. They are of a deep black colour, and in one instance had the glazed lustre occasional in this mineral. The rock varies in its constituents. On the east it is moderately pure, but seldom very crystalline. Further west, it takes a green tinge, and in certain spots feldspar or quartz is visible in grains. It is often traversed by beautiful and strong veins of quartz, clouded green and red. The compact black species contains much olivine, and some elongated crystals of hornblende.

From hence to the river Missassaga, another appearance is noticed. The islets of granite return, intermingling with the trap, both rocks being in the form of low oblong smooth mounds; the granite taking a northerly direction, and the trap running south-west. Some of the islets possessed the calcareous girdle before mentioned.

Being delayed at a point 10 or 12 miles west of the Missassaga, for thirty-six hours, I examined the beach of the mainland for one or two miles.

I here met, protruding from the woods into the lake, a rock, which is an intermixture, on a large scale, of a light-coloured greenstone, and a compound of white quartz and red feldspar minutely blended, but the latter predominating. These two aggregates mutually penetrate and traverse each other in the most capricious forms (as in marbled paper). They are in equal quantities; each being indicated by strongly contrasting configurations, knotty, straight, waved, or stellular. Ramond compares the contortions and confused appearances of certain rocks in the Pyrenees, to the effect produced by a mixture of differently coloured glutinous liquors, issuing from separate vessels at the same time, or to convolutions of smoke. These comparisons apply well to the masses under consideration *.

These mounds exhibit no tendency to stratification; but their long diameter appeared to be always directed to the north-west. They are found westward for some miles near the shore, accompanied by a few granitic mounds, holding a northern course.

The limits of this rock are not known. It is succeeded on the west by the morasses about Thessalon river. It has given the name of Le Serpent to that part of the north shore in which it occurs. Greenstone slate †, lying beneath a granular quartz to be noticed hereafter, is found in one of the islands forming the insular groups north of False Detour. The granular quartz of Green Island is succeeded on the west, after a small interval of marsh, by various greenstones, extending along the north side of the channel and narrows of Pelletau.

At the lower end of the broad promontory constituting the east side of Portlock Harbour, and in the small isles on its east, the greenstone is dark and compact, but here and there rendered slaty by weathering. It contains, in patches, numerous masses of the red ingredient of the rock of Le Serpent, from one to eighteen inches in diameter; all bearing positive marks of attrition to a moderate degree, and sometimes becoming so plentiful as to make the rock a decided conglomerate. Proceeding still westwards, by degrees the red ingredient disappears altogether, and the greenstone resembles a splintery slate, commonly of a dark leaden hue, which runs however either rapidly or gradually into cream-colour, red, blue, or light green. Its course is distinctly

* A somewhat similar rock appears to have been found by Dr. MacCulloch in the Isle of Arran, not far from Glenleg. Vide *Western Isles of Scotland*, vol. ii. p. 399.

† The greenstone slate of the northern shore breaks, often, with a very sharp edge and conchoidal fracture.

north-west; and it dips at a high angle to the north-east, when not absolutely vertical.

The greenstone of the large island close to Portlock Harbour varies much. In one part it is nearly pure hornblende, splitting into cubic blocks; in another it gradually resumes its conglomerated state, the nodules being small and rare. At the south-west end it is very slaty for a square mile.

At the place where the hornblende abounds, thin waving veins of ligniform asbestus are common. The centre only of the vein is pure, the sides passing into greenstone. Vertical seams of quartz, with drusy cavities of quartz crystals, are often met with; and thready veins of galena also. I found a mass of this ore loose, on the opposite side of this channel, weighing one pound and a half.

The precipices and steeps of the main in the Narrows of Pelletau are also greenstone; but, as usual, of different aspects. The bluff at the lower end is only slightly slaty. It contains a confused mass of quartz veins, with a small quantity of copper pyrites, and the carbonate of that metal. The middle portion of these cliffs is extremely splintery, and appears to be ferruginous. At the head of the Narrows the greenstone is much less disintegrated, and dips into the clear and deep waters in compact black walls. I have passed a league into the interior from the Narrows and Channel of Pelletau, without finding any remarkable difference in geological structure between the interior and the shores. The contiguous islets are of a similar formation, and are composed of aggregated ridges rising to a great height.

These greenstones dip from the secondary strata on the south, in the same manner as at Malbay, 90 miles below Quebec, gneiss and mica-slate dip from, and abut against, a horizontal calcareous conglomerate full of organic remains, and, among others, of three species of orthoceratite.

Having now described, as far as my information extends, the primitive rocks of Lake Huron, I proceed to notice the secondary rocks of the same district. They are a portion of an immense basin, which, extending probably without interruption from the southern shore of Lake Winipeg, spreads itself over the greater part of Lakes Superior *, Huron, and Simcoe, the whole of Lakes Michigan, Erie, and Ontario, much of the western part of the state of New York, the whole of the states of Ohio, Illinois, Indiana, and Michigan, and the rest of the valley of the Mississipi. In describing the southern boundary of the primitive chain, I have already traced the northern and eastern limits

* Dr. Wright, Inspector of Hospitals, has a specimen of chalk from the neighbourhood of Lake Superior.

of the basin in question: its southern limits, as far as I am aware, are only to be found in the Gulf of Mexico, with numerous interruptions, however, from the older rocks in Pennsylvania, Virginia, Alabama, &c. On the west it is bounded very irregularly by the primary districts that lie to the west of the Mississipi (from which it does not deviate far), and to the south and west of Lake Superior. The basin has been represented to extend as far westwards as the rocky mountains; but Mr. Schoolcraft has shown that the rugged country about the mouth of the Missouri consists of gneiss, with primitive limestone intermixed; and on further research, primary rocks will probably be found still further southwards.

The connexion of the secondary with the primary rocks of Lake Huron has been very imperfectly examined; and, in fact, is almost wholly concealed by the thick vegetation of those islets where the contact of the two formations does occur: or, in other cases, by the wide intervening tracts of water.

I shall first notice those rocks, which, though not primary, possess less decidedly a secondary character.

About the river Thessalon, on the large island opposite to, but seven miles distant from, its mouth, and in the insular groups of the lake, north of False Detour, my friend Major Delafield (American Agent under the 6th and 7th Articles of the Treaty of Ghent) observed a granular quartz, forming the north points of the islands, and dipping north, at an angle of 45°. On one isle it was remarked to run imperceptibly into the greenstone slate that lay beneath it. In High-cliff Island the granular quartz forms a precipice 100 feet high. On this island limestone containing orthoceratites is met with, which appeared to Major Delafield to alternate with the quartz. This quartz rock is frequently seamed with white quartz, of which blocks, containing much chlorite earth, lie loose on the shores. It is always hard, minutely granular, and now and then very crystalline. It contains no petrifactions.

This rock extends westward as far as Green Island, and is then succeeded by the greenstones on the north of the Channel of Pelletau.

Immediately on passing into the Lower Basin discharging into the Narrows of Pelletau, a quartz rock shows itself obscurely among the marshes about St. Joseph; but from the insular barrier to Lake George, it is abundant, and has a north-west course, and a dip which is either vertical or not discernibly otherwise. At the barrier it consists of minute grains of vitreous quartz, cemented by the same substance, rather powdery, opaque, and white. It is somewhat easily frangible. Its fissures are sometimes lined with brilliant red quartz crystals.

The islands on the north of the Upper Basin, about the Narrows of Pelletau, are of the same rock, with the same direction, but possessing more compactness. At the foot of Lake George it is often crystalline, dense, slightly translucent at the edges, conchoidal in fracture, but frequently also foliated; the fragments then becoming schistose, with a shining lustre. It is here very commonly a conglomerate rock, of great beauty, studded with nodules of red and brown jasper, averaging an inch in diameter, and usually arranging themselves in the form of belts or stripes, from one to five feet in breadth. Black and brown hæmatite occur sparingly at this place.

Two broad strata of greenstone occur in this rock, three miles apart; the lowest five miles from the Narrows, whose rock it resembles, though it is more syenitic.

The character of the sandstone, which I am now about to describe, appears both in the position of the strata and in the texture of the rock itself, to be decidedly different from the preceding.

The greater part of Lake George, as well as of the Straits of St. Mary, rests (I believe) on a horizontal red sandstone. I have observed in various parts of this lake, large slabs of this rock, with sharp fresh edges, most of it soft, and of dull lustre; but frequently quite crystalline, and remarkably hard, and white with large ferruginous red spots.

Coasting the northern shore of Lake George, towards dusk, in a canoe, I fell in with a number of islets, with cliffs of brownish horizontal sandstone strata, breaking into parallelopipeds. At the portage of the Falls of St. Mary, this rock prevails *in situ,* especially in the half-inundated islets surrounding the Rapids.

It is in horizontal layers, eighteen inches thick. It is soft, splits readily, and its principal colours are red, brown, or dull white, with frequent spots or circlets of yellow.

The sandstone is environed by morasses, but re-appears largely on the south side of Lake Superior; and an active search would perhaps discover it *in situ* near Michilimackinac, where I have seen much of its debris, and where there is gypsum.

The shores of the main and islands near Michilimackinac present, for the most part, only beaches of shingle, and rarely afford traces of rocks *in situ.* At the Isles of St. Martin, however, we find a large deposit of gypsum. It is an extensive bed, of the granular kind, white, gray, and brown, interspersed with frequent masses of red, white, and brown selenite, occurring in shapeless lumps, in veins, or in small and very thin tables, having three or more sides, and sharp angles.

The horizontal sandstone, above described, in its general characters, and in its association with gypsum, is closely allied to the red marl of English geologists, and to the old red sandstone of Werner; and in these particulars it agrees with the sandstone of the Genesee, in the state of New York, pronounced to be the old red sandstone of Werner by the very eminent Maclure.

Connected probably with the horizontal sandstone are the calcareous rocks of the island of Michilimackinac. Their character is well developed at the end of the north-east cliff, adjacent to the fort. At the top of the cliff a few horizontal strata, very thin, white, and soft, appear: but immediately below, the limestone loses the appearance of stratification, and becomes yellow and ragged. The texture of much of it is compact; but it is more usually vesicular (as if from bubbles of air), the sides of the vesicles being encrusted with crystals of quartz, in botryoidal clusters. A few of these vesicles are 3 or 4 feet in diameter, and contain several series of smaller cavities. About the middle of the western side of the island there is a cave, about 7 feet deep, formed by the confluence of several of these bowl-shaped hollows or vesicles, whose interior is here also subdivided into smaller cavities.

Other parts of the limestone, contiguous to the vesicular, are an aggregate of short angular fragments of slaty limestone and broken flints, in the greatest disorder, the interstices being empty, and lined with quartzose crystallizations. The fragments are from 1 to 8 inches in diameter, and they also are of an ochry yellow colour. The vesicular limestone and the breccia are nearly equal in quantity.

The bottom of the cliff consists of horizontal and moderately thick strata of limestone-slate, of a white or blueish-white colour, very soft—so much so as even to write. In some parts of the island the limestone contains a few blue and white striped flints. The limestone-slate forms the floor of the lake for miles around, and in some part of the island or other may be found at every level. After a careful search, I met with no organic remains in this limestone. A friend met with a single bivalve, which may have come, however, from a distance, as I observed on the isle several loose fragments, bearing the incisions observed in the limestone of the Little Manitou.

The cavernous and brecciated limestone of Michilimackinac seems to be allied to the magnesian breccia, which, at Bristol and in other parts of England, is connected with the red marl. I have stated that this limestone is probably connected with the red horizontal sandstone of Lake George. My reasons for being of this opinion, independent of those founded on the local proximity of the two formations, are, that in all the other lakes, and in Lower Canada, throughout the whole of the valley of the St. Lawrence, in the lake and territory of Michigan, and in the Illinois, similar beds of horizontal sandstone, supporting beds of horizontal limestone, are found to be the exclusive and predominating rocks.

The remaining secondary beds, which I have to describe, are calcareous. I shall divide them into two species,—the limestone of St. Joseph and the isles on the northern shore, and the limestone of the Manitoulines; not intending thereby to decide that they belong to formations essentially different, but only to distinguish the one from the other, by reason of their difference in character, in organic remains, and in geographical position.

The limestone of St. Joseph and the northern isles, is, wherever I have examined it, horizontal. It occurs usually in weathered crumbling ledges, seldom exceeding six feet in height; or it floors the beaches in broken pavements, advancing far into the shallow waters.

This species assumes various aspects in distant parts of the same level; but it is most commonly of different shades of brown and green. It is earthy, rather soft, knotty and slaty.

In the Channel of Pelletau it is granular, passing into compact, and then differs little in hand-specimens from the Dudley Rock in Staffordshire; having, like it, much disseminated calcspar.

In this channel, and in the isles near St. Joseph, it is frequently an aggregate of microscopic globules, opaque, and of a Dutch-green colour, mixing in spots with limestone of the granular or crystalline texture. In the Narrows, this oolitic species presents translucent nodules, less than a pin's head, which I believe to be quartz; especially as a quartzose conglomerate is immediately at hand. On Green Island the green colour is often very strong; and the stratum contains a number of brown oblong nodules, as large as millet-seeds. The rock rests upon a blackish-brown limestone-slate, seen only under water, and as truly schistose as that of Niagara.

The limestone of Thessalon Isle, in which the new species of orthoceratite (Pl. XXV. fig. 1, 2, 3) is found, is decidedly magnesian; and in the compact parts of it has the saccharoid texture belonging to dolomite. Its cavities, and those of the organic remains, are lined with primitive rhomboids of the triple carbonate of lime and magnesia.

There is little doubt but that the secondary belts of the primitive rocks in the islets about La Cloche and the French River, are of the St. Joseph species of limestone. The limestone here lies in horizontal beds; it is much darker than that of St. Joseph. Its texture internally is firm; but it crumbles into knotty flakes. I only observed bivalves in it, but others have seen orthoceratites in some of the westernmost of the isles*.

* The occurrence of similar belts of secondary strata, crowded with organic remains, and rest-

Rhomboidal pearlspar and dog-tooth calcspar are the only accidental minerals I have met with in the limestone of St. Joseph.

This bed is rich in organic remains, and some of them are new. Their substance is not silicified, but remains calcareous.

Wherever this limestone occurs, orthoceræ are very abundant, lying heaped thickly together in small patches through the rock; so that when the surface is exposed, innumerable sections of them are displayed. They are accompanied by milleporæ, madreporæ, encrini, shells, &c. The orthoceræ are never entire upwards; but it is by no means uncommon to find the lower termination complete, the chambers and the siphuncle extending regularly to the bottom. They vary much, not only in their absolute size, but in their proportions. They are seldom less than 2 inches broad at the larger end, and are usually from 10 to 18 inches long. Some taper so imperceptibly, as in short pieces to appear almost cylindrical; and I have seen specimens only 3 inches broad at the top, that were 4 feet long: generally, however, they are broader in proportion to their length. Major Delafield and others have seen them 6 feet long.

† Their lower termination is either acute, as in the specimen, Plate XXVI. fig. 5, from St. Joseph's; or round and obtuse, as in the specimens, Pl. XXVI. fig. 3 and 6, from an island off the northern shore, near Thessalon.

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ing in undisturbed horizontality upon the older rocks, is common in both the Canadas. Thus, at the Falls of Montmorenci, 7 miles below Quebec, gneiss dipping south-east, almost vertically, is covered by horizontal layers of limestone breccia and limestone, the latter containing the Conularia quadrisulcata of Sowerby, and, among other species of trilobite, that figured in Plate IV. fig. 5, 6, 7, 8, of the *Mémoire sur les Crustacées Fossiles*, by MM. Brongniart and Desmarest, from specimens found at Llandeilo, and preserved in the Ashmole Museum at Oxford.

Limestone breccia reposes horizontally on highly inclined mica-slate at Malbay. Repeated instances of the same kind are met with in the St. Lawrence among the Thousand Isles, the great breach of Lake Ontario. Here both sandstone and limestone in horizontal beds overlie gneiss, the limestone being without organic remains, but having imbedded in it splendid masses of sulphate of strontia. I have seen each rock in contact with the gneiss, in places 40 miles apart, but at the same level.

A decidedly crystalline texture often prevails in the limestones of the Canadas, but rather in the higher layers than in the inferior; and this crystalline limestone is universally crowded with organic remains. Thus at the Falls of Montmorenci, and at Point aux Trembles, 30 miles above Quebec, it is seen loaded with organic remains, and particularly with large pointed orthoceratites, 300 feet above the St. Lawrence, capping a succession of horizontal beds of black and brown granular limestone, with few organic remains. At the Bridge of Jacques Cartier, and at the Falls of the Chaudiere on the Ottawa, crystalline limestone is found in a similar position: it abounds at the east end of Lake Ontario. The crystallization in these cases is genuine, and does not depend on the presence of encrinitic remains: the facets are rhomboidal. The limestone is fetid.

† Excepting figures 3, 6, and 11, all the drawings are of the natural size.

Their transverse section is more frequently oval than circular; but both forms occur.

The column is divided into chambers from the top to the bottom by septa, which are usually concave toward the larger end; but in three specimens, which I am inclined to consider as orthoceræ, Pl. XXVI. fig. 3, 6, and 11, found by my friend David Thompson Esq. in the island above referred to, near Thessalon, the septa are convex upwards.

The interval between the septa, or the depth of the chambers, is for the most part either constant in the same individual, or diminishes toward the lower part of the column; but in two specimens (see Pl. XXVI. fig. 3 and 9), the former from the island near Thessalon, the latter from St. Joseph's, the depth of the chambers varies irregularly in different parts of the same column. In different individuals of the same species, the greater the column the greater is the depth of the chambers; but in different individuals of different species, the depth of chambers bears a variable proportion to the size of the column. In one of the specimens above referred to, fig. 11, the column of which is five inches broad, and diminishes rapidly, the chambers are very shallow and numerous. Figures 2 and 3 are in the most usual proportion.

In some species the siphuncle is near the centre, in others near the circumference; and when eccentric, in those species that are oval, it is usually placed in the shorter axis of the section. In the same species the diameter of the siphuncle is in proportion to that of the column, but in different species the proportion of the two diameters is very variable. In Pl. XXVI. fig. 8 and 1, the siphuncle is larger in comparison of the column, and in Pl. XXVI. fig. 10 is smaller than is usual.

The siphuncle, longitudinally considered, is in some instances a continuous tube, regularly tapering from the top to the bottom; in others it is contracted in its passage through the septa, and enlarged in the intervals between them (see Pl. XXVI. fig. 2), as in the O. cordiformis of Sowerby. An orthoceratite from Malbay has the same character.

In figure 7 there is the appearance of a small interior tube within the siphuncle.

In figures 1 and 8, where the siphuncle is large, there are peculiar markings at the upper end, which doubtless are connected with the organization of that part. I have seen other instances of this in larger specimens.

In fig. 6 the siphuncle is marked along the side by a series of broad arrowheads, pointed upwards, and diminishing as they descend. They are merely superficial markings, corresponding in number with the chambers. This specimen is 5 inches broad at the top, and 13 inches long.

Among the specimens that I have seen, are some which strongly resemble the following species figured in Sowerby's *Mineral Conchology:* viz. O. flexuosa, O. Steinhaueri, O. gigantea, and O. cordiformis.

In the magnesian limestone of Thessalon Island are found many casts of orthoceræ of a conical form, with blunt hemispherical terminations and concave septa, resembling in their general external outline many of the known species; but having a siphunculus of a very remarkable structure, which differs from any thing known respecting this part in any of the chambered shells. Pl. XXV. figures 1, 2, 3, are drawings of different specimens of this fossil.

The siphuncle is large, placed laterally, and has an enlargement in each interval between the septa. A tube runs down the axis of the siphuncle, to the sides of which, at the middle of each enlargement, it sends off, at right angles to itself, a number of radii, in verticillations, like spokes from the centre of a wheel. The radii appear to vary in number, and cannot be accurately counted, owing to the state of their preservation, as they are covered completely with small crystals of pearlspar. Their number, however, is about 16. In those places whence the radii spring, the tube has enlarged rings: between these rings are elevated longitudinal ridges leading to the radii. The tube diminishes in size toward the lower end of the column; but does not always taper regularly, nor, in different specimens, to the same degree.

Small branched corals are common, and I have found retiperæ and chain-coral: turbinoliæ of large size, and well preserved, are abundant.

Cylinders, slightly conical, perfectly smooth externally, from 1 to 2 inches in diameter at the large end, and from 3 to 18 inches long, are frequently found among the remains of orthoceræ. I have not seen their terminations. They consist, within, either of granular limestone, or of confusedly crystallized white calcspar, not radiated as in belemnites.

Neither any root nor head of an encrinite has been found on Lake Huron, nor, to my knowledge, in America. The columns of encrini are exceedingly numerous in the limestone of St. Joseph and the north; but they are without lateral arms.

The Entrochus lævis, annulatus, verrucosus, and prominens of Miller are the most abundant. Their diameter is the same as is usual in English specimens, and their length from 8 to 14 inches. Several specimens are covered with a coralline net-work.

Pentacrinites are common, but very small. The bivalves have not received attention: terebratulæ are met with. Among the univalves, euomphali and cirri have been found.

Several new species of trilobite have been found at St. Joseph's, one of which is represented in Plate XXVII.

I am obliged to Charles Stokes, Esq. for a communication respecting the specimen fig. 1: for which see the Appendix to this Paper, page 208.

The Manitouline limestone is separated on the west and north from that of St. Joseph by waters, low woods, and morasses, nothing being visible near the promontory of the True Detour for many miles around, on the shores of the main, and of the neighbouring islands, but limestone-shingle, white, slaty, and devoid of petrifactions. On the east the Manitouline limestone is connected by a chain of high and rocky islets with Cabot's Head. I have seen numerous specimens from both extremities of this ridge; but it is with Drummond, Little Manitou, and the west end of the Grand Manitou, that I am personally conversant.

Thick vegetation, debris, and the displacements usual in uncultivated countries, prevent an accurate examination of the different successive beds of this chain; which are to be considered, however, as belonging to one formation, —from their intimate geographical connexion, from their regular horizontal position, and from their containing in distant parts of the chain the same organic remains: but, as is the case with secondary rocks in all parts of the world, their character differs perpetually in places situated on the same level, or even in juxta-position. This limestone is distinguished from that of St. Joseph and the north by its greater compactness and hardness, by the difference of its organic remains, and by the silicified state in which they are found; all the fossils of Drummond being quartzose or chalcedonic, those of the Little and the Grand Manitou, and of Cabot's Head and its vicinity, being less purely so *.

This limestone rises usually to the height of 250 feet above the level of the lake, rarely at once in one abrupt precipice, but oftener in confused stair-like ledges.

The beach at Collier's Harbour in Drummond Island is in some parts floored with a brown, compact, hard limestone; almost, if not entirely, devoid of organic remains. It is massive: its surface is usually full of conical cavities, often confluent, about an inch in diameter, and from 1 to 6 inches deep. Their interior occasionally contains a series of similar cavities. A very simi-

* The substance of the testaceous remains found about Cincinnatus, in the state of Ohio, in parts of Lake Michigan, and in the route from that lake by the Wisconsin river to the Mississipi, consists of fine white quartz. The cellular and chain madrepores, turbinoliæ, tubipores, retipores, and shells of the north-east end of Lake Erie, resemble those of Dudley in Staffordshire, and are cherty.

lar stratum occurs, at the level of the lake also, at the north-west end of the Little Manitou, and at the south-west angle of the Grand Manitou. In the Little Manitou it contains anomiæ, which abound at the south-east angle of the island.

On proceeding inland, at Collier's Harbour, at an elevation of 100 feet, we find ledges of very hard quartzose white or light brown limestone, piercing the sides of the slope, and finally, in somewhat slaty and squared blocks, contributing to form Blockhouse Hill. The fractured surface of this rock sparkles with what the frequent crystallizations in cavities and fissures show to be quartz. It is in this neighbourhood that the nondescript madrepore hereafter to be described is principally found. The angle of Drummond, on the north of the False Detour, and part of the western end of the Grand Manitou, rise in cliffs 250 feet high. The rock, in both cases, resembles the quartzose limestone of Collier's Harbour. Major Delafield found the summit of the former to be a platform, crowded with ammonites and anomiæ. The latter, to judge from its debris, contains the same organic remains as Blockhouse Hill. It abounds with astreæ, and chain-coral, 2 or 3 yards in diameter. Its fissures are frequently lined with honey-yellow talc-spar. To the south of Drummond is an isle, almost wholly composed of iron pyrites, mixed with some brown calcareous matter and quartz nodules.

In parts of the Little and of the Grand Manitou, the limestone on the shore is of a blueish gray or light brown colour, very finely granular, and extremely slaty. It divides into small fragments no thicker than paper, which are arranged by the wave, edgeways, in undulating lines round the boulders on the beach. I could not find in it any organic remains; but trilobites have been met with in a rock so similar, found in loose fragments on the shores of Drummond, that I believe them to occur imbedded in this limestone-slate.

Immediately above this slaty bed, or alternating with it, in both Manitous, is a stratum, which occurs in thin broken patches, and is brown, and almost black in parts. It is very soft, of coarse texture, and full of knots of all sizes. These knots in the Little Manitou are very fetid, and often send off several short round branches. They often bear strong marks of cellular madrepore. This is by no means so slaty as the contiguous bed. It abounds in organic remains, some of which are peculiar to it: others are common to the Manitoulines.

In the middle of the north side of the Little Manitou, 30 miles east of Collier's Harbour, and 100 feet above the level of the water, in low interrupted cliffs, we find a dull-brown granular limestone, rather hard and slaty, fetid, and free from shells. We have the same rock at the same level in the Grand

Manitou; but there it is not fetid. Specimens from Cabot's Head, the Flower-pots, and the Fourth Manitou, resemble the fetid limestone of the Little Manitou: they are darker, coarser, very fetid, and abound in the petrifactions common to this range.

The fissures and surfaces of the limestone strata of the Little Manitou are marked by singular scarifications, not observed in any other part of Lake Huron. They are narrow and shallow, as if made with a penknife, and occur either singly at hazard, or forming a multitude of parallel incisions, placed together promiscuously. They crowd the surface of the rock and of the various organic remains. Their greatest length is an inch, their ordinary length much less. Sometimes they are only punctures, of triangular, rhomboidal, oblong, or semicircular shape.

On the south-western shore of Lake Huron, at Presquisle, the limestone is only seen at the bottom of the harbour, forming a broken pavement, on a level with the waters of the lake. It differs little in appearance from the fetid limestone of the Little Manitou, being brown, granular, and tolerably hard; but I did not ascertain its fetor. It contains the organic remains prevalent in the limestone of the Manitoulines *.

The limestone of Middle Island resembles that of Presquisle, and is full of organic remains.

The organic remains of the Manitouline limestone have been collected principally in Drummond, and chiefly through the persevering exertions of Mr. M. White of the Army Medical Staff. This island having been assigned

* I found at Presquisle a loose fragment of limestone, having the peculiar suture observed in that of Kingston on Lake Ontario. This limestone is subdivided, not only by the horizontal planes which render it schistose, but by other planes which also are horizontal. The upper and lower surfaces of these partitions are covered with a brown or black shining matter. They are extremely rough, from their mutually sending forth innumerable processes of the most irregular shape, protruding from half an inch to $2\frac{1}{2}$ inches, which are received into corresponding depressions in the opposite surface. A section of the partition resembles the suture of the human cranium: like which, the limestone suture can be taken asunder and replaced without fracture.

The 11th stratum from above, at the Table Rock of the chasm of Niagara, is intersected 5 or 6 times in this manner. This suture has also been observed on Lake Erie, in white granular limestone; and in Lower Canada, at Point aux Trembles and Point Levi, in brown fetid crystalline limestone. It has been found also in the river St. Clair, in loose fragments of black fetid crystalline limestone.

At Point Levi, and in several of the strata at the great chasm of Niagara, it is very minute, and leaves the horizontal direction, wandering about in the most fantastic curves. It often extends only to a little distance, and disappears as a very small fissure, coated with a thin black scale.

by the Commissioners under the Treaty of Ghent, to the United States, the British garrison will be withdrawn; and as it will not be held as a military post by its present owners, it will be long, probably, ere its fossils again become the object of research.

The first of the organic remains which I shall describe, are some corals found in the quartzose limestone at Collier's Harbour, and at the west end of the Grand Manitou, differing from any that have yet been discovered in a recent or fossil state. Their variations of external form are such as to have led me to separate them into five species; and as it is in that particular alone that they differ, it is of one only, and that the most abundant, that I have given a detailed description; contenting myself, as to the rest, with pointing out those changes of form which distinguish one species from another. The figures are all of the natural size.

Species I.—The corals of the species represented in Plate XXVIII. fig. 2, have in their general appearance a considerable resemblance to vertebræ. They are columns, tapering from the top, composed of similarly formed joints, which diminish downwards both in length and breadth, though not in regular gradation. The length of each joint in this species is about an inch, and the breadth exceeds the length. The transverse section is circular. The lower and middle part of each joint is cylindrical, or slightly conical; the upper part swells out, and is inflected inwards at the top, so as to meet entirely the base of the joint next above it. This dilated part is, in different species, in very variable proportion to the rest of the joint. The lower part of one joint is inserted, to some little depth, into the upper part of that next beneath it, so as to attach the joints firmly to one another. The external surface is covered over with a thin smooth coat; but this is rarely preserved, and then only in small portions. The surface is usually without this coat, and is then longitudinally striated.

Where the joint is most dilated, a thin horizontal septum, formed by the abrupt inflexion inwards, and coalescence of the upper and lower parts of the outer coat, passes transversely across the joint; as is seen in two of the joints in figure 2.

The section represented in fig. 6 shows the radiating lamellæ peculiar to madreporæ, and the congenerous lamelliferous corals. These lamellæ are longitudinally disposed, and radiating from the axis of the column to its parietes, there form the external striæ.

In the axis of the column is a hollow tube; but the whole interior of the column is in most specimens obliterated, being filled with dark granular limestone, or with quartz, having carious holes or cavities, lined with rock crystal. The substance of the coral itself is silex, with a slight calcareous admixture.

Including all the species, I have seen sixty specimens of this fossil; but in no instance has either the base of the attachment, or the upper extremity of the column, been preserved. The greatest length of any column that I have seen is 27 inches. The columns are not found in groups, but single, mixed with turbinoliæ, chain-coral, encrinites, &c.

Species II. Pl. XXVIII. fig. 1.—This species is the largest. The greatest length that I have seen in any joint has been $1\frac{7}{8}$ in.; of which the diameter at the base was $1\frac{5}{8}$ in. The greatest diameter I have seen at the base of any joint, has been $2\frac{3}{4}$ in., the length of the joint being $1\frac{2}{5}$ in. The upper part of each joint is much less inflated in this than in the first species.

Species III. fig. 3.—In this species, which is the smallest I have met with, the column tapers more rapidly, the upper part of each joint is more enlarged, and is greater in proportion to the rest of the joint, than in the two foregoing species.

Species IV. fig. 4.—In this species the plane passing through the line of the base of each joint, is oblique to the axis of the column.

Species V. fig. 5.—In this species the cylindrical part of each joint disappears, and the joint assumes the form of an oblate spheroid.

Many other species of coral are also met with in Drummond Island.

Of astreæ I have seen six or seven species, one of them considerably resembling the lithostrotion of Llywd.

Of the genus Porites, or madreporæ of Lamarck, one species.

Of Caryophyllia one species, which merits a more detailed notice. It is represented in Pl. XXIX. figures 1 and 2. The former figure shows the outside and the base of the coral, and exhibits a peculiarity which is quite new, I believe, to corals of this genus. Tubes appear branching from the outside, and communicating with the interior. Most of these are broken off; but one of them remains, which is three-fourths of an inch long, and takes an ascending direction. In fig. 2, tubes are seen near the base, which take the contrary direction. It is difficult to imagine what purpose these branches could serve in the former case; but in the latter they might assist in strengthening the base of attachment of the coral. I have in my possession a specimen from Collier's Harbour, containing a group of eleven of these corals, closely crowded together.

Turbinoliæ abound in Drummond. The different species vary in size, from $\frac{1}{4}$ in. to 10 in. in length; the larger being sometimes 4 inches broad at the upper end. I have seen 21 of these corals in one mass, each 10 inches long.

One species, which is common, resembles that from Italy figured in Parkinson's *Organic Remains*, pl. iv. fig. 9.—Plate XXIX. fig. 3. represents the smallest species. Figure 4 is remarkable for the spiral curvature around the centre of the radiating lamellæ. Other species are represented in figures 5 and 6.

The chain-coral (Tubipora catenula, Gmelin; Catenipora escharoides, Lamarck) is common; as also the Tubipora Strues, Park. *Org. Rem.* pl. ii. fig. 1, and Tubipora ramosa, *Ibid.* pl. iii. fig. 1.

Small retiporæ, and milleporæ, are abundant.

Of shells there are many species of terebratulæ found near Collier's Harbour, and a large species is common near the True Detour, and in the cliffs near the False Detour, where it is accompanied with ammonites.

Of orthoceræ there are some remains; but they are not so abundant in Drummond as in St. Joseph's or Thessalon Islands. Among them one species has a considerable resemblance to O. annulata of Sowerby. Pl. XXX. figures 1 and 2, represent two fragments, which resemble those figured in Breynius's *Dissertatio de Polythalamiis*, tab. 6, fig. 1 and 2.

Another class of fossils from Collier's Harbour differs from any thing I have seen. They are columns, usually tapering rapidly, composed of circular discs, with rounded edges, placed one upon the other. Each disc is from $\frac{1}{3}$ to $\frac{1}{8}$ in. thick, and from $\frac{1}{4}$ to 2 in. in diameter. They vary much among themselves. Thus Pl. XXX. fig. 5, is of considerable length, and tapers very gradually. In fig. 3 the diminution is rapid. In fig. 4 there is a sudden diminution from a large to a small size. In fig. 6 the column is curved; in fig. 7 the discs are placed obliquely.

The entrochites mentioned among the organic remains of St. Joseph and the north occur in Drummond also, but sometimes of twice the size. The Pentacrinite is also met with.

The Little Manitou, in addition to the turbinoliæ, and most of the other corals of Drummond Island, possesses several species of organic remains, which are found no where else throughout the Manitouline chain. They occur in the knotty stratum: but as they are but obscurely defined, I shall pass them over.

On the Foreign and Native Debris of Lake Huron.

The shores and bed of Lake Huron appear to have been subjected to the violent action of a flood of waters and floating substances rushing from the north. That such a flood did happen is proved, not only by the abraded state of the surface of the northern mainland and scattered isles of the Manitouline range, but by the immense deposits of sand and rolled masses of rock which are found in heaps at every level, both upon the continent and islands: and since these fragments are almost exclusively primitive, and can in some instances be identified with the primitive rocks *in situ* upon the northern shore; and since, moreover, the country to the south and west is secondary to a great distance, the direction of this flood from the north seems to be well established.

The boulders of granite, gneiss, mica-slate (rare), greenstone porphyry, syenite, and various amygdaloids, are principally of such varieties of these rocks as I have not met with *in situ*, either in the neighbourhood of Lake Huron, or in a journey of 600 miles which I made to the east and north-east of the lake, through the forests of the river Ottawa.

Of mica-slate I met with only two fragments, of a brown colour, among the trap isles. A fragment of serpentine was found in Drummond, on Blockhouse Hill.

The greenstone porphyries have a light-coloured base, and contain crystals of red or white felspar—seldom of both in the same block. I have seen boulders of the porphyry with red felspar, on the Ottawa, 500 miles to the east of Lake Huron. The syenites are the same as those of Europe.

The amygdaloids are often coloured brown by iron, and then contain almond-shaped masses of epidote only. The green varieties contain nodules of agate * and red jasper, white amethyst, epidote radiating upon layers of quartz and small garnets.

It can scarcely be doubted that these rocks will be found *in situ* somewhere on the northern shore of Lake Huron, between the Missassaga and Pelletau's Channel. It is there and on the Isle of St. Joseph that their boulders most abound. Together with the fragments of the above-mentioned rocks, are found others of trap, greenstone-slate, greenstone-conglomerate, jasper-conglomerate, and quartz rock. These occur in every part of the lake, but most abundantly near their parent rocks. The conglomerates closely resemble those which have been found on the northern shore *in situ*. The base of the conglomerates is either quartz or greenstone. Of the quartzose conglomerate the nodules consist rarely of white translucent quartz, sometimes of greenstone; and more commonly of red, green, brown, black, or parti-coloured jasper. In some instances pieces of quartz—rarely of greenstone—are mixed with those of jasper. The greenstone conglomerates contain nodules, either

* Agates, jaspers, &c. are found abundantly as pebbles, on Lake Superior and about the Missisipi.

of quartz, of greenstone, or of the red ingredient found in the rock of Le Serpent. This latter conglomerate has been noticed as occurring *in situ* in the Channel of Pelletau.

It is only about the Narrows of Pelletau that the rock of Le Serpent has been seen in a rolled state. Breccias similar to the conglomerates are not uncommon; but I have never found them *in situ*.

Pebbles of red sandstone, and quartzose or slaty limestone, have a very limited range: they only now and then wander as far as the Manitoulines, the southern shore, or Michilimackinac.

I have already noticed the quantity of primitive boulders found on the Isle of St. Joseph. The beach of the rivers Thessalon and Missassaga is covered by boulders of black trap, granite, gneiss, and jasper-conglomerate.

The Georgian or Penetanguishine arm of the lake is loaded to excess with sand and rolled pebbles. Penetanguishine, and much of the south-east coast of this arm of the lake, is a collection of sand-hills, enveloping quartzose, granitic and amphibolic blocks of all sizes, and in vast quantity.

Passing into the southern division of the lake, 64 miles south of Cabot's Head, the limestone cliffs of the Manitouline range are succeeded by cliffs of clay. From this point beds of clay, covered towards the upper part of the river St. Clair by thick beds of sand, extend for 150 miles to Lake Erie, and thence along the northern shore, which presents a series of clay cliffs and sand-hills, to the north-eastern extremity of the lake. The whole of the intervening shores and woods are strown with rolled blocks of gneiss, porphyry, conglomerate, and greenstone, such as prevail on the northern shore of Lake Huron. In a south-westerly direction, the clay-beds prevail over the Michigan territory, and the states of Indiana and Illinois, to an unknown distance. In the two last-mentioned states (which I have not visited) rolled blocks abound.

The argillaceous and sandy banks of the southern shore of Lake Huron are conspicuous near Point aux Barques, in the Gulf of Saguina, and about Presquisle. The debris of the rocks of the northern shore are here rare, and much rolled.—Staurotide was picked up on the southern shore by Mr. Schoolcraft.

Besides the sand and boulders before spoken of, which are ancient, and have travelled from a distance, there are fragments of another character, which may be called *native*, reposing on the parent rock, or not far removed from it. This debris is comparatively recent, having been detached by various natural causes, such as torrents, change of temperature, &c. The latter agent operates either by the expansion and contraction of the rock itself, or of the water contained within its fissures. In the spring the nocturnal frosts and diurnal thaws are very violent. In the winter the thermometer is frequently 50° below the freezing point, and in summer it ranges from 60° to 90° of Fahrenheit. I once saw it at noon, on the 20th of June, 1820, at $101\frac{1}{2}$° in the shade.

These recent fragments, whether of the older or newer rocks, are angular and mostly small, and cover their parent rocks, as well in the high as in the low grounds, often to the depth of several feet. Examples of this are seen in the slaty greenstone of the Narrows, in the quartzose limestone of Drummond, and in the quartz rock at the foot of Lake George.—All the countries to the north of Lake Huron are loaded with similar debris. The French river, in one wild spot, the scene of an Indian massacre, is almost choked with it. In Lake Nipissing, near its southern shore, there is a large heap of square clean masses of gneiss piled together promiscuously.

An instructive fact is presented by many parts of Lake Huron, and very strikingly in the channels of Pelletau. It shows that the recent debris is nearly stationary. The opposite shores of this channel consist of different rocks, the one being limestone, the other greenstone. Each shore is lined with its own debris, without any admixture, except that of rolled pebbles of granite, pudding-stone, or greenstone, left by the debacle on the calcareous beach.

In the spring the ice occasionally removes fragments of great size: the inhabitants of Quebec annually see them transported in this manner down the St. Lawrence. During the winter the ice surrounds the blocks that are upon the shallows; and on being broken up in May, it carries them by a rise of water to some other shore. Remarkable instances of this are found on the islets near the south end of St. Joseph; where, a few yards from the water, and a little above its level, rolled stones, many feet in diameter, are found deposited, with a furrow extending from the water to their present place of rest.

That changes in the level of Lake Huron have occurred, and that its surface once stood much higher than at present, is proved by the traces of ancient beaches and zones of rolled stones and sand that are found in the neighbourhood of the lake. Such an occurrence has been noticed in Collier's Harbour, at Blockhouse Hill, which has the appearance of a beach, and of having formed the west end of the Isle of Drummond, when the lake stood higher than at present. Similar alluvial ridges are found surrounding the other lakes and rivers in Canada. These may be accounted for partially by the effects of the wind; which, blowing strongly from certain quarters for a few days, accumulates the water on the leeward coast, the waves there washing up the shingle in scalar ridges to the height of 6, 8, or 10 feet.

On concluding this Memoir, I have to express my grateful acknowledgements to Sir James Macgregor, and to Dr. Wright (Inspector of Hospitals), for their zealous aid, afforded to me when prosecuting these researches.—Mr. M. White of the Army Medical Staff will also accept of my best thanks for various acts of kindness. Mr. Parkinson and Mr. C. Stokes have most obligingly given me free access to their libraries and collections.

APPENDIX.

I. *On a Trilobite from Lake Huron.*

BY CHARLES STOKES, ESQ.

"In breaking away the rock from a specimen of trilobite found at St. Joseph, and now in my possession, a fortunate fracture exposed a small part of the under side of the fossil; and encouraged me, as the rock was of a favourable texture, and the fossil in a good state of preservation, to attempt a further dissection, in the hope of laying open some parts of the animal with which we have hitherto been unacquainted; and I discovered the part forming the entrance into the stomach. Its structure, which considerably resembles that of the analogous parts in some recent crabs, will be best explained by the accompanying drawing (Pl. XXVII. fig. 1. b.). I have frequently attempted to cut away the rock from specimens of trilobite from Dudley; but owing to its hardness, I have not yet succeeded in developing any thing similar."

II. *List of some of the Recent Shells of Lake Huron.*

I am obliged to I. E. Gray, Esq. of Burton-street, Burton Crescent, for the names of some recent shells which I collected in Lake Huron.

Helix albolabris, . .	Say *Amer. Conchol.*	T. i. fig. 1.
—— alternata, . .	————————	T. i. fig. 2.
—— angulata ? . .	Rackett *Linn. Trans.* vol. xiii.	
Planorbis trivalva, . .	Say *Amer. Conchol.*	T. ii. fig. 2.
Lymnæa Catascopium,	————————	T. iii. fig. 3.
——— heterostropha,	————————	T. i. fig. 6.
——— (Nov. Spec.).		
Physa (Nov. Spec.).		
Valvata (Nov. Spec.)		
Cyclostoma tricarinata,	Say *Amer. Conchol.*	
Cyclas (Nov. Spec.).		

III. *Account of an Explosion in a Vein of Pyrites.*

This explosion took place, sixteen years ago, in the township of Yonge, near the Lake of the Thousand Isles in the St. Lawrence. At the time, a man was seeking his cow in the woods, within a short distance of the spot. On a sudden he was startled by a tremendous explosion, attended by volumes of smoke, and sulphurous odours.

Three years since, on being informed of these particulars, I visited the place. It is half a mile within the woods north of the road from Brookville to Kingston, near to the easternmost of two creeks, about ten miles from the former town.

I found, on the summit of a quartzose mound from 30 to 40 feet high, a round cavity, 12 feet deep, 12 long, and 9 broad. Its sides consisted of very shattered quartz spotted brown by oxide of iron, and covered profusely with acicular yellow and white crystals of sulphur. The lower parts of the cavity were studded with masses of iron pyrites, of which there is a vein at the bottom of the cavity. It is a foot and a half thick, and disseminates itself into the surrounding quartz. This vein may be seen, running east with a very high dip, to the distance of a yard and a half.

Similar phenomena have been noticed in a mountain in Vermont (vide *American Journal of Science* for Feb. 1821), and in the country towards the head of the Missouri (vide *Travels of Captains Lewis and Clarke*).

XV.—*Observations on the South-western Coal District of England.*

By the Rev. W. BUCKLAND, B.D. F.R.S. V.P.G.S.,
PROFESSOR OF GEOLOGY AND MINERALOGY IN THE UNIVERSITY OF OXFORD,

AND

The Rev. W. D. CONYBEARE, M.G.S. F.R.S.

Chapter I.—GENERAL OBSERVATIONS ON THE DISTRICT.

Introduction.

THE district, which we purpose to describe in the following memoir, comprehends the several coal-fields which lie near the estuary of the Severn and the Bristol Channel, including parts of the adjacent counties of Gloucester, Somerset, Monmouth and Glamorgan.

These coal-fields, though apparently distinct and insulated, are yet connected together by resting on a common base of old red sandstone. They all appear to have been formed by similar agency, and at the same era; to have been subject at a later period to the same revolutions; and, lastly, to have been covered partially by similar overlying deposits. The many particulars, therefore, which they supply in illustration of one another, and their contiguous geographical position, have induced us to collect into one Memoir the materials that we have obtained concerning them.

Of the great coal-field of South Wales, however, the most extensive of those within our district, we have reserved a full and detailed account for a separate communication; and have here restricted ourselves to such a general description of its eastern limits only, as may serve to point out its connexion with the other coal-basins adjoining.

The district to be examined is of the highest interest to the scientific geologist, as serving to establish the relations of some of the most remarkable British rocks; it is of importance to the practical miner, from its numerous strata of coal and iron-ore, so opportunely associated together, and from the limestone-beds which border on the coal, and are employed to flux the iron-ore. Mines of lead-ore and calamine add to the mineral riches of the district: they are worked, however, with little spirit, and are not very productive.

On the two Series of Rock Formations.

Two great series of rocks occupy our district, the distinction between which is strongly marked, every circumstance seeming to indicate the lapse of a considerable interval of time between the deposition of the last beds of the former series and the first beds of the latter.

The first and lowest of the two series is composed of those rock-formations, which, commencing with the grey-wacké slate and other transition-rocks of the Wernerians, terminate upwards with the independent coal-formation of the same school. The highest of the transition-rocks graduate so insensibly into the lowest of those which succeed to them *, that it is difficult to assign the precise limits at which the former are to be considered as ending, and the latter as beginning. The distinction between the remoter parts, however, is sufficiently obvious.

The rock-formations of the first series, beginning with the lowest, are the following:—

1. Grey-wacké.
2. Transition limestone.
3. Old red sandstone.
4. Carboniferous or Mountain-limestone.
5. Coal-measures.

The second and uppermost of the two great series of rocks comprehends some of the lowest formations, termed *floetz* by the Wernerians. This series reposes on the first. The members of this series, which we here have occasion to treat of, beginning with the lowest, are the following:—

1. Newer red sandstone: comprehending
   - *a* Dolomitic conglomerate †,
   - *b* Red sandstone,
   - *c* Red marl.
2. Lias.
3. Oolite.

* One of the authors has elsewhere expressed his opinion on the misapplication of the epithet "floetz" to the three last rocks of the first series. See *Outlines of Eng. Geol.* book 3. chap. 1. Were the term *first floetz* applied to the carboniferous limestone, it must produce confusion between English and Continental geologists; for the latter uniformly apply that term to the limestone associated with the bituminous marl-slate of the Hartz, Mansfield, &c., which is now universally admitted to be contemporaneous with our newer dolomite. On the old and newer red sandstones, see Appendix to this memoir.

† At the suggestion of our friend Mr. Warburton, and on the more recent authority of Von

All these formations which have here been simply enumerated, will be defined and fully described in the course of the present Memoir.

On comparing the strata of the two great series of rocks, the first circumstance that forces itself on our attention, is their difference of inclination to the horizon. Those of the first series are generally highly inclined, and exhibit marks of disturbance in every form of fracture and irregular position. Those of the second series, on the contrary, are either perfectly level, or inclined imperceptibly to the horizon: they seldom show traces of internal derangement, and they rest transversely on the truncated edges of the strata of the former series. The horizontal formations, throughout the greater part of our district, are confined to lower levels than the inclined, and form upfillings (as they are termed) between the loftier ridges, into which the inclined strata ascend on emerging from the horizontal deposits thus partially spread over them.

Such being the covering by which these older formations are invested, and such the irregularities of their stratification, it is only by multiplied observations on the character and dip of the strata, as displayed in their scattered and seemingly independent masses, and by a comprehensive study of those observations, that the geologist will be able to ascertain that a determinate succession prevails in the order of the inclined strata; and thence that he will be able to infer the former or actual continuity of those masses, and trace from one part of the district to another their relative bearings and connexion.

The order of super-position in the inclined strata being very regular, scarcely less so than in the overlying, it seems probable that they were formed originally in a nearly horizontal position, and that they owe their present fractures, curvature, and elevation, to convulsions long subsequent to their being formed; and since the internal derangements which affect the inclined strata very rarely extend to the overlying ones, the disturbing causes, it should appear, were of high antiquity, and anterior to the deposition of the overlying beds.

The entire want of conformity between the two series of rocks causes the lowest of the overlying strata to come into contact indifferently with any one of the inclined beds. It is impossible, therefore, at a given spot, without in-

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Buch, we have substituted the term "*dolomite*" for magnesian limestone. That definite triple salt, the carbonate of lime and magnesia, when found native in a state of purity, and associated with primitive rocks, has received the name of dolomite; and it is the same chemical salt, rendered impure by iron or bitumen, or by carbonate of lime, intimately but mechanically blended with it, which occurs in our first and second series of rock-formations, and has there been called magnesian limestone. It appears to us desirable to use but one appellation for substances not essentially differing in chemical constitution.

vestigating the subterranean geology of the inclined beds of the district, from the mere occurrence at the surface of the rock which is the lowest in the overlying series, to augur respecting the inclined stratum that shall be found beneath the overlying one. Those persons must therefore be in error who, from an existing superstratum of red marl, and from that occurrence only, are led to infer the existence of coal-measures lying beneath it *.

On the Mode of Distribution and Local Extent of the Rock Formations of the First Series.

From extensive observations made on the dip of the inclined strata throughout the district, we find that they are subject to undulations, which dispose them into a number of basins of less or greater extent, according as those undulations are more or less rapid, the strata dipping from every point in the circumference of each basin towards its centre.

These basins are divided from one another by lines, which may be termed *anticlinal lines*, formed by the saddles of the strata, or meetings at the surface of their vertical angles; on either side of which the strata dip in opposite directions. For rendering the structure of such a country, as relates to the inclined strata, intelligible, it is of the first importance to determine the position of these lines, and thus resolve the district into its component basins. We have therefore endeavoured to represent the course of these lines in the accompanying Map.

Sometimes these lines follow the crests of the chains of hills (see Fig. 1); sometimes they are to be traced along the course of valleys (see Fig. 2): the hills in the latter case being formed, not by the saddles of the strata, but by the escarpments cutting through them.

Fig. 1.

Fig. 2.

To apply these principles to the district before us.—The grey-wacké and the transition limestone appearing in but few places, the old red sandstone may be considered as the fundamental rock of the district. The undulations of the fundamental rock will determine those of the super-strata of the same series; since the upper and lower strata are parallel with regard to each other.

* See Mr. Warburton's "Observations on the overlying strata in the neighbourhood of Bristol," printed in the 4th volume of the *Geological Transactions*, 1st series.

The coal-measures, therefore, will occupy the interior of all the basins thus constituted, and will be surrounded by exterior bands of mountain-limestone and old red sandstone, in the order of the outcrop of the subjacent beds.

The principal basins of the district, which include as many principal coal-fields, are three :—

1. That of Somersetshire and South-Gloucestershire ; which for brevity we shall call the Basin of Bristol.

2. That of the Forest of Dean.

3. The great coal-basin of South-Wales.

We shall now trace the boundaries of these three coal-basins, as far as they fall within the geographical limits to which we have confined ourselves.

1. *Boundary of the Coal Basin of Bristol*.*

This basin occupies an irregular triangular space, the base of which on the south is the chain of the Mendip Hills, a high range of mountain-limestone, running from east to west, and resting on an arch of old red sandstone. The sandstone appears, with some interruptions, in the central region of the chain, of which the longer axis coincides with the anticlinal line. The calcareous isle of Steepholm is placed on the prolongation of this southern frontier, and connects it with a collateral branch of the limestone boundary of the coal-basin of South Wales.

The northern apex of the triangle is at the village of Tortworth in Gloucestershire. The western frontier of the basin is continued from the Mendips to this apex ; not by an unbroken chain, but by three lofty insulated groups, placed on the same line of bearing, and parted by narrow intervals, of which the broadest falls short of three miles. These interruptions, or rather depressions in the chain, are occasioned by undulations in the bed of limestone, which dip (to emerge from them again) beneath the horizontal deposits ;

* A valuable Paper by Dr. Bright, describing the natural section of the strata at the defile of the Avon, and supplying the key to the geological structure of the entire district, was read at the Meetings of the Geological Society in the year 1811, and published in their Transactions in the year 1817. The Bristol Coal-basin has been well described by Mr. Townshend in his "Character of Moses," published in 1813; and subsequently by Dr. Gilby in a Paper inserted in the Philosophical Magazine.—In a Note appended to the Paper of Dr. Bright, Mr. Warburton has made an important observation on the dolomitic conglomerate, regarding it as the equivalent of the magnesian limestone of the North of England; and in a Paper inserted in the same volume of the Geological Transactions, Dr. Gilby has taken the same view of the subject. Some Notes of the late Professor Tennant on the dolomite of the Mendips will be found annexed to this Memoir. The foregoing are the principal authorities from which we have derived advantage, in drawing up our account of the "Bristol Coal-basin."

more or less completely filling these depressions. The three insulated members of the western calcareous frontier are, 1. Broadfield Down, of which Worleberry and the calcareous islet of Flatholm may be considered the extreme western prolongations; 2. Leigh Down, comprehending the defile of the Avon, and the hills stretching thence to Westbury; 3. the range commencing at Knoll park and the Ridgeway near Almonsbury, and thence running by Thornbury to Tortworth.

The old red sandstone is seen in many places accompanying this western interrupted calcareous chain, either forming an arch in its centre, or rising from the foot of its escarpment in the plains to the west of it. The latter is the case towards the northern part of this western frontier, where the anticlinal line, separating the coal-basin of South Gloucestershire from that of the Forest of Dean, seems to pass along the middle of the valley of the Severn.

Transition limestone emerges from beneath old red sandstone at Tortworth, and, passing the Severn at Pyrton-passage, is united to the exterior chain of the Forest of Dean.

Near Tortworth, at the northern apex of the triangle, the range extending from Almonsbury is deflected abruptly to the south, and in that direction, constituting the eastern frontier of the basin, it may be traced through Wickwar to Sodbury. From Sodbury to the eastern extremity of the Mendips near Mells, the southern half of the eastern frontier is concealed by overlying deposits, except at three points of very limited extent at the northern foot of Lansdown near Wick rocks, where valleys of denudation, cut down through horizontal lias, have exposed the limestone, dipping there, as in every visible part of the boundary, towards the centre of the coal-basin. From the foot of Lansdown to the Mendip hills the continuity of the coal-basin is well ascertained, either by valleys of denudation which cut through the horizontal deposits down to the coal-measures (and in such valleys are situated the principal collieries of Somersetshire), or by frequent shafts opened in the same deposits, beneath which the coal is worked. From the dip of the coal-measures, wherever proved in the interval referred to, it may be concluded, that the subterraneous prolongation of the eastern frontier of the basin coincides very nearly with a line drawn from Wick rocks to Mells.

2. *Boundary of the Coal-basin of the Forest of Dean.*

This basin occupies an irregular elliptical area, circumscribed by the triangle formed by the Wye, the Severn, and the road from Gloucester to Ross, the longer axis from north to south being about ten miles in length, and the transverse from east to west about six miles. Together with its exterior chains it constitutes a mountain group, whose average height above the sea is about 900 feet.

With one partial interruption, on the south-east frontier near Lidney, a band of mountain limestone succeeded by old red sandstone may be traced entirely round the basin. To the west and south-west exterior chains of mountain limestone and old red sandstone cross the Wye, and are prolonged to a considerable distance between that river and the mouth of the Usk, forming the mountain chains of Penca-mawr and the district of Gwent. Transition limestone is found on the western side of the basin near Usk. The narrow and rocky defile of the Wye, from a little below Ross to Chepstow, traverses strata of mountain limestone and old red sandstone, the coal-measures being entirely confined to the district north of that river. On the north-east also, near Mitchel Dean and Longhope, exterior chains from this basin are prolonged to some distance beyond the coal-field. They exhibit in succession mountain limestone, old red sandstone, and the inferior beds of transition limestone, resting finally against the elevated strata of greywacké, which compose May-hill.

The transition limestone of Tortworth, after crossing the Severn, together with the old red sandstone at Pyrton-passage, may be traced due north through Flaxley to the exterior chain in question, which, forming a narrow ridge, extends from Longhope to the Marcle hills and Stoke Edith, four miles east of Hereford.

3. *Eastern Boundary of the great Coal-basin of South-Wales.*

The general features of this basin are well known from the description of it by Mr. Martin, published in the Philosophical Transactions for 1806. The following general statement may be added concerning the exterior chains of its eastern portion, as they serve to connect it with the coal-basins of Bristol and the Forest of Dean.

A band, formed by the outcrops of the beds of mountain limestone, surrounds the eastern part of this coal-basin. This is succeeded by the old red sandstone, the fundamental rock on which the basin here reposes. The beacons of Brecon, the loftiest mountains in South Wales, being 2862 feet above the sea, are entirely formed of this rock, as is the whole chain connected with them which skirts the basin parallel to the valley of the Usk. Greywacké appears at the Eppyent hills in Brecknockshire, to the north of this chain of sandstone. On the east, the old red sandstone occupies the base of the limestone escarpment, and extends over nearly the whole of the district between this escarpment and the similar one of the Forest of Dean. On the south, the sandstone may be traced accompanying the limestone escarpment through the valley of Llandaff and the river Ely (though here partially concealed by the horizontal deposits) to the neighbourhood of Cowbridge; but being covered over by an investment of mountain limestone at Penline Castle, near Cowbridge, it appears no more on the east side of the bay of Swansea. From Penline Castle a collateral branch of the calcareous chain, dipping west-south-west, is sent off towards the east-south-east, which skirts the south side of the valley of the Ely from Cowbridge through St. Lythian's Down to Wenvoe and Dinas-Powis, 3 miles west of Cardiff*. Thus the vale of the Ely is flanked on both sides by an escarpment of bands of limestone, dipping in contrary directions: on the north, by the exterior chain of the coal-basin, dipping towards that basin, and extending from Penline Castle through the New Forest to Pentirch, the lowest part of the chain being in the vale of the Ely, 3 miles to the south of Llantrissant: on the south, by the collateral branch of St. Lythian's Down, dipping towards the Bristol Channel. The old red sandstone forms an arch on which the two calcareous chains repose; the keystone of the arch being in the middle of the vale of the Ely, along which the anticlinal line extends.

On the Mode of Distribution and local Extent of the Rock Formations of the Second Series.

In that part of the great escarpment of the horizontal strata which lies wholly to the east of the coal-district, the overlying series of rocks, to reckon from the newer red sandstone upwards, is usually found entire, the lowest members of the series being seldom or never wanting. It might therefore perhaps be expected that the same law should prevail throughout the whole coal-district, and wherever within its area the overlying formations occur, that there should be found invariably the lowest member of those formations incumbent on the older rocks. Such, however, is not invariably the case; but a rock, which is usually intermediate in the system, will frequently be found to be the lowest. The newer red sandstone, or its subordinate conglomerate, is not always present as the lowest of the horizontal strata; nor, the sandstone or its conglomerate being wanting, is the lias then always the lowest; but the oolite is sometimes found reposing immediately on the inclined beds; and it will appear from examples in the sequel, that either red marl, lias, or oolite may be placed immediately in contact with the older rocks. The whole structure of this district, it is to be remembered, presents the in-

* We beg to refer to Mr. Greenough's Map of England for a clear geological representation of this part of the basin. See also the Section at Pl. XXXIV. fig. 2 and 3 of this Memoir.

tersection of strata disposed in horizontal planes with strata disposed in inclined ones. A stratum of the horizontal series appears to occur most uniformly when its planes, on being continued from the district in which it prevails, are not interfered with or intersected by the planes of the inclined strata; and such a stratum, on the contrary, appears to be most frequently wanting, where steep and prominent ridges are formed by the inclined strata projecting above the level to which the planes of the horizontal stratum would extend. Where-ever such ridges ascend above the prevailing level of a horizontal stratum, we may expect the more recent horizontal strata, whose prevailing level is more elevated, to form immediate contact with the inclined rocks.

From the total want of conformity between the two series of rocks, we have already deduced the consequence, that the lowest of the overlying deposits may be placed in contact indifferently with any one of the inclined rocks. We may now derive the still more general consequence from this want of conformity, that any member of one series may be in contact with any member of the other.

Of the red marl and of the lias the prevailing levels are such, that they form moderate acclivities* within and without the coal-basins, and are rarely found investing the highest crests of the older chains; but the oolite at its great escarpment maintains so high a level, that it forms lofty eminences within the coal-district itself; and would also probably have been found on the loftier of the ancient ridges; but its course to the westward is very limited, and it scarcely begins to reach the eastern extremity of Mendips, when its beds are discontinued and terminate altogether.

The great escarpment of the oolite forms the natural boundary of the coal-district on the east. It runs from the Cotswold hills by Lansdown, west of Bath, presenting a lofty chain between 800 and 900 feet above the sea. To the west of the principal escarpment it throws out many insulated masses, of which Dundry hill, situated to the south of Bristol, is 790 feet above the sea.

The formations of the red marl and lias compose the covering or mantle which immediately surrounds the frontier of the Bristol coal-basin. On the south they fill the interval between the Mendip and Quantoc hills†; on the west they are found extensively on the shores of the estuary of the Severn; on the north they occupy the plain extending from Berkeley to Gloucester; and on the east they form a continuous band, interposed between the foot of

* Lias, however, often occurs in Somersetshire at 500 feet above the sea.

† For a description of the rocks of the second series in this quarter, we beg to refer to Mr. Horner's paper "On the Geology of the South-west part of Somersetshire," printed in the 3d volume of the Geological Transactions.

the oolite escarpment and the outer ridge of the coal-field. After closely skirting this ridge, and occasionally overlying it, they finally towards the south surmount the eastern frontier, and pass within the basin. In this south-eastern part of the coal-field, the shafts, by which the coal is won, are frequently opened in the red marl, in the lias, or even in the lower beds of the oolite.

It is only on the eastern and south-eastern frontiers of the two remaining coal-basins that the horizontal deposits of red marl and lias are found, when they face the similar deposits that skirt the eastern shores of the Severn and the Bristol Channel. From the nature of the islets in the Channel end of the shoals laid bare at the lowest ebbs, it appears that these deposits compose the whole bed of the estuary, extending from shore to shore, except when removed by denudation or the more recent action of the tides. Wherever this removal has been effected, the older ridges are discovered extending across the Channel.

The coal-basin of the Forest of Dean being altogether mountainous, while the horizontal deposits prevail at the low level of the valley of the Severn, those deposits are confined to the foot of the outer ridges of the basin, which border on the western shores of the Severn and the Bristol Channel. They are not found protruded within the area of coal-field itself, nor do they surmount that mountain-barrier to reappear on its western frontier.

We may trace their course along the right bank of the Severn from the southern extremity of the Malvern hills to the northern prolongations of the Forest of Dean, and thence beneath the eastern escarpment of the ridges of the Forest to Caldecot level at the base of Penca-mawr, and to the flats extending to the mouths of the Usk and Taaf.

But of the horizontal deposits which occur on this side of the estuary, the most extensive are those in the southern part of the vale of Glamorganshire. Here they occupy the whole tract between the Bristol Channel and the collateral limestone range of St. Lythian's Down*, lining the coast, from the mouths of the Ely and Taaf to that of the Ogmore, with a range of cliffs, which face towards the same formations on the opposite coast near Watchet. Lias occupies nearly the whole of this tract, except in the parish of Sully, where the red marl and dolomitic sandstone occur extensively.

The vale of the Ely is also covered in many places by these deposits, which here rest on old red sandstone.

They also fill† an extensive cavity, formed by the vale of the Ewenny and the lower part of that of the Ogmore, near Bridgend, whence they pass through

* See the Sections, Pl. XXXIV. figures 2 and 3.

† Consult Mr. Greenough's Map of England.

the valleys eastwards to the neighbourhood of Llantrissant. These deposits are protruded within the great Glamorganshire coal-basin, reposing partly on the inner side of its southern calcareous frontier, and partly on the basset-edges of the coal-measures within the basin. Near Bridgend the lias prevails; further east the dolomitic conglomerate, beneath which, in the parish of Llanharran, coal is worked. To the west also of Bridgend we find the conglomerate; near Pyle, resting on the coal-measures; and near the sea-shore, at Kenfig, on the east side of the bay of Swansea, on mountain limestone.

Before we close this general account of the south-western coal-district of England, we are desirous of noticing its resemblance in geological structure and picturesque features to the country extending along the Meuse between Namur and Liege. There also we are presented with coal-basins encircled by mountain limestone, and based upon old red sandstone, which latter is displayed at Huy. These rocks are all highly inclined, and are covered by overlying formations. The defiles of the Sambre and the Meuse present an exact counterpart of those of the Avon and the Wye. For a most able and accurate description of this district, we beg to refer to a paper by Mons. Omalius D'Halloy, published in the 24th volume of the *Journal des Mines*.

We shall now proceed to describe in detail the two coal-basins: 1st, that of Bristol; 2dly, that of the Forest of Dean, as far as relates to the inclined strata of which the basins are composed. We shall afterwards treat, in a separate chapter, of the horizontal strata of the entire district.

Chapter II.—ON THE COAL-BASIN OF BRISTOL.

We shall first give the character of the inclined formations that compose the frontier of this coal-field; we shall next trace these formations in their joint progress round the frontier, and finally treat of the coal-measures occurring within the basin. No further mention will here be made of the overlying horizontal strata, than is necessary to explain the local phenomena connected with the appearance of the older rocks.

On the Rocks composing the Frontier of the Basin.

1. Grey-wacké.

This rock does not occur on the frontier of the Bristol coal-basin. It is found at some distance to the south of the area at the Quantock hills in Somersetshire.

2. Transition limestone.

We can scarcely regard the transition limestone as properly belonging to the frontier of this basin, since it only occurs near Tortworth without its northern apex, and is there immediately connected with extensive masses of the same rock, which form part of the northern frontier of the basin of the Forest of Dean. To the chapter therefore on the latter basin, and to the memoir by Mr. Weaver on the Geology of the Neighbourhood of Tortworth, we refer for particulars concerning this rock.

3. Old red sandstone.

This formation consists of various alternating beds of sandstone, quartzose conglomerate, and slaty marl usually much indurated. These are generally of a brick-red colour, often flecked with streaks or mottled with spots of a yellowish green colour. Sometimes entire beds are of a yellowish green, or greenish grey hue.

The sandstone usually is composed of fine grains of quartzose sand, mixed in variable proportion with red clay and mica, white specks of felspar being frequently disseminated through it. The mica, when very abundant, is disposed in rapid alternation with thin laminæ of argillaceous sandstone, then producing that fissile character which is prevalent in the beds of this formation, and occasions them to afford flagstone and coarse tiles. Except in the case of the most fissile beds, the sandstone is extremely hard and tough.

The conglomerate contains pebbles of milky quartz; occasionally of red and black jasper; and more rarely of slate. These are imbedded in a matrix of sharp, glassy, quartzoze sand, firmly cemented by red oxide of iron.

The sandy strata alternate frequently with beds of dark-brown tenacious clay, which in Herefordshire and in the vale of Monmouthshire assumes the form of a brick-red marly clay, and there gives a fertility to the old red sandstone formation as strongly characterized as is its barrenness in the Mendip chain. This sterile character is, indeed, exaggerated in the Mendips by their high elevation and exposure; the change of stratum, however, from limestone to sandstone is immediately indicated throughout the chain by a change of herbage; the surface acquiring a swampy appearance, even on the steepest slopes, wherever the sandstone begins to prevail. Occasionally a few fertile spots may be found upon the sandstone; but this is generally owing to the presence in the subsoil, whether it belong to the old or the newer red sandstone, of that peculiar red marl which forms the basis of the richest soils in the most luxuriant parts of England.

The old-red-sandstone is known throughout the district by the name of firestone, from its being employed for making hearths. In the old red sandstone of this basin only one occurrence has been noticed of those calcareous concretions which are so prevalent in the sandstone of Herefordshire and Monmouthshire, and are there denominated *cornstone*. The cornstone is mentioned by Dr. Bright, in the 4th volume of the Geological Transactions, page 201, as forming a bed three feet thick towards the middle of the beds of old red sandstone that lie beneath the mountain limestone on the left bank of the Avon.

The occurrence of vegetable impressions in this formation, on the banks of the Avon near Bristol, is mentioned by Dr. Bright in the page before cited. A similar case may be noticed in the quarries of grey and red flagstone to the west of Leominster in Herefordshire, where the vegetable remains are so abundant, as to render it probable that thin coal-seams may there alternate with the flagstone.

4. Carboniferous or mountain limestone.

The mountain limestone of this basin agrees in mineralogical character, organic remains, and geological position, with that of Derbyshire and the great central ridge of the north of England. It is in no part of the district so completely displayed, as in the defile of the Avon, which has been described by Dr. Bright and by Mr. Cumberland in the 4th and 5th volumes of the Geological Transactions. We therefore refer to the papers of these gentlemen, and to our own observations on the same defile, for a detailed account of the entire series of beds composing this formation.

The divisions of this formation, adopted by Dr. Bright, may be recognised pretty generally, wherever sections are afforded, throughout the whole exterior chain of the basin. Of these the black-rock, so called from its dark colour, one of the lowest beds of limestone, abounding in encrinites, presents the most striking features, and is most easily identified, wherever the lower strata are exhibited. Some of the beds of this formation, particularly the lower, are often dolomitic. The calcareous beds are preceded below, and succeeded above, by a set of argillaceous beds, which may be termed the lower and upper limestone-shales. The former of these occupies the interval between the old red sandstone and the calcareous beds of the mountain limestone; the latter (agreeing with the limestone-shale of Derbyshire) lies between the mountain limestone and the incumbent millstone-grit.

The lower limestone-shale consists of a soft argillaceous slate, usually of a dark greenish hue inclining to black. It contains a few subordinate calcareous beds, having the same aspect, and containing the same organic remains, as mountain limestone. It rarely exceeds 300 feet in thickness.

It may be seen upon the Avon in the wood below Cook's Folly, vide Map and Section, Pl. XXXIII. fig. 1 and 2. It forms an important feature in the constitution of the Mendips, where its extent is usually indicated by a low narrow tract of stiff wet clay-land, immediately encircling the base of the old red sandstone, and extending from that base to the dry surface of the limestone. Its exterior flank is often overhung by a precipitous scar, occasioned by the outcrop of the superincumbent limestone; which from its greater powers of resistance has been less cut away by denudation than the shale. [Vide Pl. XXXII. fig. 3. and 3. A & B.

The contact of the shale with the limestone is marked in many places by the sudden engulfment of streams, which rising in the old red sandstone, maintain their course above ground, while flowing on that rock or on the retentive beds of shale; but no sooner come into contact with the encircling zones of limestone, than they suddenly disappear in its numerous fissures and caverns *.

The upper limestone-shale may be recognised at Clifton in those alternations of shale with sandstone, impure limestone and thin seams of coal, which form a link between the subjacent beds of pure limestone and the incumbent beds of millstone grit. We comprehend under this title the beds from No. 1 to No. 46 inclusive of Mr. Cumberland's section. This shale differs from the analogous limestone-shale of Derbyshire in the oolitic structure of some of its subordinate beds of limestone, and in the abundance of red oxide of iron which pervades the whole formation. This red oxide or ruddle prevails also in the millstone and coal grits of the district, the red taking place of the grey by which the similar grits in Derbyshire are tinged.

The aggregate thickness of the beds belonging to the formation of mountain limestone, as determined by comparing their horizontal breadth with their inclination on either side of the Mendips, is from 500 to 700 yards. This is considerably less than the thickness ascribed to these beds in the defile of the Avon by Mr. Cumberland; but we shall assign the reasons for this want of agreement in our measurements, when we come to treat of that defile.

Respecting the organic remains of the mountain limestone in this basin, we

* The openings thus engulfing the streams are known provincially in this district, as well as in Derbyshire and Yorkshire, by the name of swallet-holes, being abundant in those counties, as well as in every other where mountain limestone prevails. Examples of these swallet-holes occur at Downhead Mill, near the south-eastern extremity of the Mendip chain; at the village of Priddy; and at Charterhouse, on the south-east flank of Blackdown. The exit of the streams swallowed up may be traced with much probability to the following points: that of the Downhead stream to the limestone chasm about a mile east of the village of Downhead; that of the Priddy rivulet to Wokey hole, and that of the Charterhouse brook to the foot of Cheddar cliffs. The streams which emerge are all greater, indeed, than those engulfed; but this arises probably from the tributary waters which they have received during their subterraneous course. The streams, if excessively flooded, might, after suffering partial engulfment continue to flow above ground through the valleys of denudation in which the swallet-holes are situated.

will only notice that, besides those which are most common in this formation, it contains the palates, teeth, fin-bones, and vertebræ of fishes; which serve to refute a prevailing opinion, that vertebral animals do not occur in formations more ancient than the coal-measures.

The mountain limestone, like other compact limestones, is very liable to the occurrence of caverns, of which many remarkable instances are found within our district*. They consist of a series of vaulted chambers connected by narrow passages. They are frequently traversed by streams derived from swallet-holes, but are more frequently destitute of any water, but such as percolates through the sides and roof. The strata in which they occur are in general almost wholly concealed by incrustations of stalactite; so that it is not easy to determine by observations on the strata how far the caves owe their origin to mechanical disturbance. In several instances, however, when the mouths of caverns occur in the faces of cliffs, affording distinct sections, the strata do not appear to have been dislocated, but are continuous.

Another remarkable feature in the mountain limestone is its intersection by narrow precipitous mural chasms, which lie transversely to the calcareous chains which they intersect, and to the principal lowland valleys contiguous. These often form the gorges by which the upland valleys descend into the neighbouring plains; they are then simple excavations in the limestone, unattended by any disturbance in the strata, and are the result, apparently, of the furrowing action of some violent cause, acting from without. At other times these ravines completely intersect the calcareous ridges to a depth beneath the level of the contiguous longitudinal valleys, and they then turn the rivers aside from pursuing those valleys in their course. In the latter case they are often due to internal derangements of the highest antiquity, though probably considerably modified in their forms by subsequent denuding forces. Cheddar cliff is an example of the former kind; and the defile of the Avon, which turns

* A notice of the caverns near Loxton and Banwell, in the western part of the Mendip chain, will be found in the Gentleman's Magazine for 1794. That of Hutton Hill, containing antediluvian bones, is described in the *Reliquiæ Diluvianæ*, page 57, from Mr. Catcott's notes; that of Burringdon, near the entrance of Burringdon Combe, which has served for a place of sepulture, and contains human bones incrusted by stalactite, in Collinson's History of Somersetshire. Several small caves may be seen in the face of Cheddar cliffs; as may that called the Giant's Cave in the face of St. Vincent's rocks. Penpark hole, not far from Westbury, near the outer edge of the northern extremity of Durdham Down, has been described and represented in the Philosophical Transactions for 1682. It has sometimes been considered as a deserted lead-mine; but the dimensions of its principal chambers are inconsistent with this notion, though its shaft and lateral galleries may be due to mining operations, which may have cut into this natural chamber, as in the instance of the Speedwell level in Derbyshire.

that river aside from the valley leading through Long Ashton and Nailsea to the Bristol Channel, and conducts it through the limestone chain of Leigh Down into the Severn, is a magnificent example of the latter.

Exterior Chains of the Coal-basin described.

We now proceed to trace the old red sandstone and the mountain limestone in their joint progress around the frontier of the Bristol coal-basin.

1. On the southern frontier or Mendip chain.

This is the loftiest and most extensive of the exterior chains of the basin. Its whole length from Frome on the east to Uphill bay on the west, where it is cut off by the Bristol Channel, is about 26 miles. It consists (as we have before stated in the introductory chapter) of mantle-shaped strata of mountain limestone, investing a central axis of old red sandstone. This axis is partially covered by the limestone, and partially emerges from beneath it, and then rises into four * conspicuous ridges, of which the highest points ascend to between 100 and 300 feet above the elevated calcareous table-land of the Mendips. The calcareous slopes on either side of the chain are encumbered by the overlying formations, and especially by the dolomitic conglomerate. These deposits are also frequently insinuated into the valleys between the two exterior calcareous bands, and invest extensive portions even of the high central table-land.

The first point where the inclined strata appear at the eastern extremity of the chain, is on the line of the intended canal close to Whatcomb farm, half a mile west of Frome. They are concealed along great part of the low table-land, that encircles the eastern termination of the chain, by strata of inferior oolite, and are visible only in the valleys of denudation through which the several streams pass that unite between the village of Mells and Frome. Beautiful sections may be seen in the precipitous sides of these valleys, exhibiting the oolitic strata in an absolutely horizontal position, reposing on the truncated edges of highly inclined strata of mountain limestone †. The character of these valleys is exceedingly wild and romantic from the craggy steepness of their sides, though their depth is very inconsiderable. Hence few more striking

* There is a fifth appearance of the sandstone, but to a very limited extent, in a valley at the head of Emborrow Meer.

† Vide Plate XXXV. fig. 2. At the village of Whately the two formations adhere so closely, that we have collected firmly cemented masses, of which one half is oolite, and the other mountain limestone, the strata of the two rocks intersecting at an angle of 45°. In this neighbourhood a bed of breccia is sometimes interposed, occasioned probably by the entanglement of loose gravel, previously lying on the surface of the limestone, in the first deposits of the oolite.

scenes are exhibited among the Mendip hills, than in the narrow dingles extending from Mells to Vallis-house, and along the three streams which flow northwards into the Mells river from the villages of Nunney, East Cranmore and Leigh. The dip presented in these sections shows uniformly that the limestone-strata mantle round the eastern extremity of the axis of old red sandstone, being inclined usually at an angle of about 45°, but occasionally being nearly vertical.

Towards the heads of the valleys just described, and at the distance of about 6 miles from where the inclined strata first appear, at the village of Little Elm, the Mendip range begins to assume the character of a chain of hills. Here also, in Railford Bottom, the first or easternmost nucleus of old red sandstone commences. This nucleus, running east and west, at first constitutes a narrow ridge of very inconsiderable elevation; but it increases both in breadth and height on passing the village of Downhead [Pl. XXXII. fig. 1. and fig. 1. A], and within 3 miles west of this point forms the bold and conspicuous ridge, the eastern extremity of which is called Beacon-hill. The western extremity is remarkable for the strong entrenchment of Masberry Castle*, a lofty eminence 999 feet above the sea, commanding an extensive view of the surrounding country, and one of the stations on the Ordnance survey. [Pl. XXXII. fig. 1. B.] This ridge, like most of the other heights of the Mendip chain, is covered with ancient sepulchral barrows. To the west of Masberry Castle the ground suddenly falls, and the old red sandstone becomes hidden under a mantle of mountain limestone. The length of this nucleus of old red sandstone from east to west, between Little Elm and Masberry Castle, is about 8 miles, and its average breadth from north to south about 1¼ mile. The dip of its strata, which cannot often be ascertained, is usually at an angle of 45°, and is in every direction from the axis of the ridge.

The nucleus of sandstone is skirted by conformable strata of mountain limestone, reposing on its flanks, but separated from immediate contact with it by an intervening bed of lower limestone-shale. These exterior zones however are partially concealed by the overlying deposits. Thus at Little Elm the oolite reposes immediately on the lower limestone-shale. From this point to East Cranmore the limestone becomes visible in a south-westerly direction through a tract 3 miles long and 1½ mile broad, bounded on the south-east by the course of the Cranmore brook. In the interval between the right bank of this brook and the brook of Nunney, 2 miles distant to the eastward, the low tableland of oolite, already spoken of, conceals the limestone. This same mass of

* In the ditch of the castle, at almost the highest point of the mountain, is a well of water, which is upheld by some of the argillaceous beds of the old red sandstone.

oolite, sweeping westwards, closes over the edges of the limestone strata, and abuts against the southern flank of the ridge of old red sandstone, from East Cranmore to Downside, north of Shepton Mallet; but further westwards the lias invests the inclined strata. The southern band of limestone is thus every where concealed in this tract, except in one small point called Waterlip, north of Doulting, where it emerges from under lias and is discovered in close contact with the old red sandstone. [Pl. XXXII. fig. 1. A.] At the limestone crag of Windsor-hill, situated 2 miles to the north-west of Shepton Mallet, the limestone is again exposed to view, dipping to the south at an angle of 45°, and from thence it passes round the southern and western flanks of Masberry Castle. From Masberry Castle it extends southwards over a low tract nearly 2 miles broad; but further to the south the calcareous border presents so many irregularities, that it would be tedious to follow it in a verbal description, and we must beg to refer for its outline to the map.

These irregularities are occasioned by three ridges of mountain limestone, which here lie to the south of the principal chain, and parallel to it and to one another. The valleys between them are occupied by the dolomitic conglomerate, while the higher table-land of lias, extending from Shepton Mallet, reposes in terraces upon their eastern extremities.

These ridges are, 1. Lyall-hill [see the Map and Pl. XXXII. fig. 2.] on the north of Dinder: 2. Dulcot-hill [see Map, Plate and figure last quoted], rising with a craggy mountainous outline, to the east of the village of the same name; and broken into two parts in its centre. Its strata are inclined at an angle of 30° to the south, and it is covered by the terraces of lias near a place called Dungeon. [Pl.XXXII. fig. 1. B.] 3. Knowl-hill and Worminster-hill, close to the villages of that name. They are two distinct eminences, but being placed on the same line of bearing may be considered as fragments of one ridge. [Pl. XXXII. fig. 1. B.] Where these ridges inosculate with the principal chain, near the village of Cross Combe [same Plate and figure], a most picturesque defile extends northwards, the top of which, lofty as it appears from below, is only on the same level with the lias plain extending from Shepton Mallet. The precipices of mountain limestone, which skirt it, are fringed with luxuriant woods. Near its mouth, on the east side, a large rock of conglomerate adheres to the summit of the limestone cliffs.

The northern portion of the calcareous zone, which surrounds the eastern nucleus of old red sandstone, may be traced eastwards in a straight line from the western extremity of Masberry Castle, near Slab House, to Mells. This zone, from being two miles broad near to Masberry Castle, is reduced to the breadth of half a mile at its eastern extremity. Its northern boundary coincides very nearly with the course of the stream, which runs eastward from Emborrow Meer by Nettle Bridge to Mells, and its southern with the road leading from Oakhill eastward, by Stoke-lane and Leigh, to Mells. It is flanked on the north, nearly along its whole extent, by the coal-tract, which reaches from the village of Emborrow, by Nettle Bridge, to Vobster and Mells. The strata of this northern portion of the zone of limestone dip, conformably to those of the old red sandstone, at an angle usually exceeding 45°; and at the crag of Beck Tor and Hurdlestone wood [Pl. XXXII. fig. 1.] they plunge rapidly beneath the coal-measures, at an angle varying from 75° to 90°; at Mells also and Whateley their dip to the north is scarcely less considerable.

Two circumstances affect the regularity of the stratification of this northern part of the calcareous zone.

1st. An undulation of the strata brings the old red sandstone to the surface at the head of Emborrow Meer, see Pl. XXXII. fig. 2. The low ridge to the north of this denudation, and the higher ridge to the south, present the strata of mountain limestone dipping in opposite directions; the first ascent of the southern ridge, however, is much concealed by overlying beds of chert, which will be described in our account of the horizontal formations.

2dly. Two faults, at Vobster near Mells, traverse the coal-measures a little to the north of their junction with the mountain limestone, and ranging parallel to the drift of the strata, twice throw up the limestone, and cause it to re-emerge in the midst of the coal-measures. [Plate XXXII. fig. 1. C.] The most southern of these faults is seen at Vobster rock, which overhangs the river close to the village of that name: the most northern is along the line of the intended canal, $\frac{1}{4}$ of a mile to the north of the former. The limestone is slightly contorted, but has a general dip to the north of about 60°. The coal-measures are highly contorted, and thrown into the greatest confusion.

The junction of the mountain limestone with the coal-measures between Emborrow and Mells is sometimes concealed by beds of the dolomitic conglomerate: but in Mells park, near which the conglomerate terminates, the oolite (as we have already mentioned) begins to cover the limestone.

The second nucleus of old red sandstone commences at the distance of $1\frac{1}{2}$ mile from the sandstone of Masberry Castle. Penhill, on the north of Wells, is its highest and most central point. It extends in length from north-east to south-west about 3 miles, and is from $\frac{1}{2}$ to $\frac{3}{4}$ of a mile broad. From the eastern base of Penhill this ridge suddenly slopes away to the ordinary level of the calcareous table-land at the top of the Mendips. It is surrounded, like the eastern nucleus of sandstone, by a mantle of limestone. On the south, however, the lias, based occasionally on red marl and its conglomerate, is prolonged from the platform which it forms at Shepton Mallet to the very foot of the sandstone ridge of Penhill, and partially conceals on that side the calcareous zone. [Pl. XXXII. fig. 2. and fig. 2. A.] This mass of lias forms a narrow strip more than 3 miles long, which extends from Crapnal farm near Cross Combe, on the east, by Chilcot, East Horrington, and Birrel farm, to Milton-house, near Wokey. Its western portion fills a hollow bounded partly by old red sandstone and partly by mountain limestone, and may be seen on the road after ascending about one-third of the hill above Wells. The mountain limestone protrudes itself to the south of the lias in Stowborough and Milton hills.

To the west of East Milton the dolomitic conglomerate ascends the hills to a considerable height, around the ravine which terminates in Wokey hole, which cavern, and the chasm which immediately leads to it from below, are formed in that conglomerate. About half a mile west of Wokey hole, a fine combe appears, flanked by mural precipices of mountain limestone, and known by the name of Ebber Rocks.

The tract to the north of Penhill consists of a table-land of mountain limestone, which presents no remarkable feature, but serves to separate Penhill from the northern nucleus of old red sandstone. [Pl. XXXII. fig. 2. A.].

The 3d or northern nucleus of old red sandstone is loftiest at its western extremity to the north-east of Priddy. This is the most conspicuous summit in the central part of the Mendip chain, and is called sometimes North Hill, and sometimes Eight-barrow or Nine-barrow Hill, from two groups of sepulchral tumuli on its surface. From North Hill the ridge of sandstone sweeps eastwards about 3 miles, following a curve-line concave towards the north, until it approaches a farm called Tar Hall, where a deep valley, descending towards Chewton Mendip, intersects it. [Pl. XXXII. fig. 2. A.] To the north of this valley the sandstone re-appears in Egar Hill, and there terminates. These sandstone eminences, when viewed from the calcareous table-land on the east of Tar Hall, which is there unusually depressed, appear very bold and striking. The height of the summits on either side of the Tar Hall valley is increased by a covering of a remarkable shelly chert, which we shall have occasion to notice in our description of the overlying rocks.

The band of mountain limestone, lying on the northern flank of this 3d nucleus of sandstone, is much concealed by overlying deposits. Its hangings above the valley of Chewton Mendip and the two Harptrees, are covered by the dolomitic conglomerate. The conglomerate also forms an upfilling in the higher part of the Tar Hall valley, and there spreading itself over the table-land of the Mendips, entirely conceals the junction of the sandstone and limestone within the bay formed by the sandstone ridge of North Hill. The limestone, however, becomes exposed from Wigmore farm to the miserable inn, miscalled the Castle of Comfort; but immediately to the north of the latter is again concealed by an elevated platform, consisting of longitudinal strata of the abovementioned peculiar shelly chert, reposing on strata of ochreous sand. [Pl. XXXII. fig. 2. A.] This platform, which rivals in height the ridge of old red sandstone, is about 2 miles long and 1 broad, and extends northwards in the direction of East Harptree to the edge of the mountain chain, where it terminates in a promontory projecting below two valleys, the western called Lamb-bottom*, the eastern ascending towards Green-down.

In this central part of the Mendip chain, the general bearing of its axis being from south-east to north-west, the limestone flanking it is divided into two parallel bands, having the same direction. The average breadth of the north-eastern band is rather less than from $1\frac{1}{2}$ to 2 miles. That of the south-western is somewhat greater. This latter calcareous band extends to the brow of the hills that overhang the valley of the Axe, and is uniformly covered along its hangings by the dolomitic conglomerate.

We now come to the western nucleus of old red sandstone. This nucleus, towards its western extremity, occupies a low position, and in the valley that extends from Roborough and Shipham to Winscombe and Loxton, is almost wholly concealed by overlying beds of conglomerate, composed entirely of fragments of old red sandstone and mountain limestone. At Winscombe the sandstone is partially exposed, 1st, near the church; 2dly, further to the south, immediately beneath the escarpment of mountain limestone, the interval being filled by conglomerate. [Pl. XXXII. fig. 3. B.] To the east of the road from Bristol to Cross the sandstone rises into a bold hill, distinguished by a clump of firs on its summit; and soon afterwards, near Shipham, swells into the ridge of Blackdown, the loftiest in the whole Mendip chain, being 1092 feet above the sea. Blackdown extends about 4 miles in length, from Shipham eastward to near Ubley Hill farm, and is about 1 mile in breadth. In the Roborough defile the conglomerate rises high up the northern slope of Blackdown, and resting on the edges of the sandstone, presents a bold range of crags on the western side of the ravine. [Pl. XXXII. fig. 3. A.]

* On the side of this valley is a cavern called "the Lamb Cavern," mentioned by many writers. It is not now open, but appears from the description of it given in Maton's Western Tour (see vol. ii. p. 132.) to be rather an old mine than a natural cave.

The sandstone is separated from the limestone by intervening beds of shale, which, having readily yielded to denuding forces, is usually excavated into a line of valley. The denudation of the shale is so deep and sudden at the foot of Blackdown, that high precipices are formed by the truncated edges of the incumbent beds of limestone in the scar of Shute-shelf Hill on the south, and of Burringdon ham on the north. The blue varieties of the lower limestone-shale, along the southern base of Blackdown, so nearly resemble in external appearance the shale of the coal-measures, as to have occasioned several fruitless and expensive trials for coal. Shafts have been sunk with this view in the limestone-shale, under the scar of Shute-shelf, and further eastwards near to Charterhouse farm. Had these shafts been deep enough, they would have penetrated to the old red sandstone.

This elliptical tract of old red sandstone and limestone-shale, exceeding 8 miles in length, is completely encircled by a zone of mountain limestone, except at a lateral opening near Loxton, about $\frac{3}{4}$ of a mile broad, through which the streams, collected in the western half of the inclosure, find their way into the Axe.

This calcareous zone, though of inferior height to the sandstone summits of Blackdown, is yet of considerable elevation. In the scars both of Shute-shelf and Burringdon ham the limestone strata are highly inclined, in the former to the south, in the latter to the north; and they would, if continued, form an arch over Blackdown. In the northern band of limestone, at the entrance of the Rowborough defile, in Doleberry camp, we have a curious instance of fan-shaped stratification, a section of which is represented in Pl. XXXII. fig. 3. A.

Both the northern and the southern limestone-ridge is broken through by transverse valleys, which, when near together and precipitous, intercept detached summits, affording, from their steepness and insulation, positions of great military strength. Thus, on the northern side of the chain we have the fortified positions of Banwell and of Doleberry, the latter bounded on the west by the defile leading from Churchill to Rowborough, and on the east by the ravine of Burringdon Combe: on the southern side of the chain we have the conical summit of Crook's Peak, which yielding but little in height to Blackdown, and much exceeding it in the mountainous character of its outline, forms one of the most striking features in the western portion of the Mendips. From Cross to Cheddar the southern declivity of the chain towards the valley of the Axe is unusually abrupt, and the transverse valleys which penetrate into it, are distinguished by a wild and rocky character. We have here two striking ravines; viz. that of Tining's gate, and the yet more stupendous chasm of Cheddar cliffs, which rivals any of the wildest defiles in the highest mountains of the British Islands *.

To the west of the gorge of Loxton the double band of limestone becomes united into a single saddle-shaped ridge, and is so continued to the extreme western point of Bleydon-hill, near Uphill, at the mouth of the Axe, where the chain gradually sinks to a level with the sea †. The strata dip on either side

* We here insert some notes on the geology of this part of the Mendip hills, by the late Smithson Tennant, Esq., which have been communicated to us by Mr. Warburton.

"Going westward from Cheddar along the foot of the mountain, you arrive at a rocky combe, at the bottom of which on the eastern side the strata consist of magnesian limestone, and dip to the south; on the western side the strata have the same dip, but consist of common limestone. Higher up the combe is seen a rugged mass of re-cemented magnesian limestone. The mass is triangular with its point downwards; it ascends only ⅔ds of the slope of the hill. Is this mass part of a stratum, or has it been washed here in fragments, and deposited on the surface of the limestone?

The next combe has masses of re-cemented magnesian limestone on its eastern side. Another gap, which admits of a road from Shipham to Axbridge, has masses of the same rock on its western side.

The next break, which is by far the most considerable, admits the road from Bristol to Cross. Regular strata of magnesian limestone, dipping to the south, are here cut through to let the road run level. In quarries to the east of the road the rock is generally reddish, but sometimes coloured green by chlorite. It is filled with entrochi, and some imperfect and broken shells. The shells and entrochi are not magnesian, but partly calcareous, partly siliceous. To the west are quarries for mending the road, in which are masses of chert imbedded in magnesian limestone. Above the level of the magnesian strata, both to the east and west, is blue limestone. Going westward towards Crook's Peak, projecting strata of limestone and magnesian limestone are observed; the most western part of the Peak is principally magnesian limestone, of a dark grey colour, and very hard. Crook's Peak terminates this southern ridge of the Mendips, but another ridge which extends to the Bristol Channel lies a little to the north of the former. This northern ridge consists of alternating strata of common and magnesian limestone. About 2 miles east of Bleydon, near a lime kiln, the contact of the two rocks may be observed. The strata dip to the south. Where the two rocks are in absolute contact, there is a mutual intermixture of substance to the depth of an inch or two; but fragments of the size of an egg may be obtained, in which the two rocks are so distinct, that one side will be dissolved in acids rapidly, the other slowly. Sometimes there is an interval between the two rocks, which is filled with red crystals of quartz. At the distance of 1 mile from Bleydon the magnesian limestone is found of a dark blue or grey colour. Near Bleydon are raised flattish blocks of a light buff-coloured re-cemented magnesian limestone, consisting of that substance in the state of sand, including angular fragments of the blue variety just mentioned. The paste is occasionally impure from an admixture of iron and clay; the blue parts in some places contain shells."

† For an account of the cavernous fissure in mountain limestone at Hutton-hill on the northern slope of this ridge, which, together with ochre, ochreous clay, and fragments of limestone, was found to contain the bones of ante-diluvian animals, see *Reliquiæ Diluvianæ*, p. 57. At Banwell also ochre either is or has been dug in fissures of the limestone. In both these cases it seems to be of diluvian origin.

of this ridge in the direction of its slopes, the nucleus of old red sandstone being continued probably beneath the saddle of limestone.

On the other side of the mouth of the Axe is the insulated hill of Brean-down, composed of mountain limestone dipping to the north conformably to the northern flank of the Loxton chain, of which it is the continuation; and on the same line, at a little distance from the shore is the isle of Steep-holm*, consisting of a saddle of mountain limestone. The stratification is not very distinct, but presents at the eastern extremity of the isle a remarkable undulation in the form of an arch.

Before we quit the examination of the southern frontier of the basin, it may be expected that we should take some notice of the mines for which the Mendip hills were once celebrated. They are now however of very little importance as objects either of mineralogical or of economical attention. The mines of calamine, which are the principal that are now worked, occur, not in the inclined strata, but in the overlying conglomerate, and will be noticed therefore in a subsequent part of our paper. The lead mines are almost entirely abandoned; they have been worked principally in the mountain limestone.

Galena is the only ore. The gangue is calcareous spar, mixed occasionally with a little sulphate of barytes. The veins are very thin, and we have not been able to learn that they affect any certain direction. Though the principal lead-mining district is between Emborrow and Priddy, yet there is scarcely any part of the calcareous ridges of the Mendip, in which shafts have not formerly been opened. The marks on the map will indicate these points more clearly than a verbal description. The workings are universally shallow; they are undertaken only by the mining peasantry of the neighbourhood, with the rudest machinery and most limited capitals; and the water no sooner flows in, than the works are necessarily abandoned. It has probably been ascertained by experience that there is little chance of obtaining profitable returns from any more extensive system of operations. If it be asked, how we are to account for the numerous traces of former workings while so few pits now remain open, the answer seems to be, 1st, That formerly the upper part of the veins was not exhausted, which alone can be productive under so imperfect a system of working; 2dly, That formerly, when the means of transport from one part of England to another were less perfect than at present, the price of

* The isle of Steep-holm is, as its name denotes, precipitous and craggy. The summit, which is not accessible without some difficulty, presents an uneven surface of a few acres, covered with coarse herbage and weeds, among which the Peony grows wild. The isle is not habitable, nor applicable to any useful purpose; there are, however, the ruins of a small hovel near the top.

the metal throughout the whole country did not depend on its cost of production in the richest mining districts, and might therefore be remunerative in some poorer district sufficiently remote from the markets of the most productive in metal.

Manganese is dug about East Harptree; and was so formerly, but sparingly, in a vein on the summit of the limestone ridge about a mile east of Shute-shelf.

2. On the western frontier of the Coal-basin.

We will first notice two ridges of limestone, those of Worleberry and Woodspring, which may be considered as appendages indifferently either to the southern or western frontier. They lie to the north of Loxton-hill, the western extremity of the Mendip chain, at the distance of two and four miles respectively, and run from east to west parallel to that chain and to one another.

Worleberry-hill*, the most southerly of them, is about 400 feet in height, and nearly 3 miles in length. Its strata dip to the south at an angle of 45°. On the east, at the village of Worle, they rise abruptly from beneath horizontal beds of conglomerate and lias; and terminate on the west in a precipitous cliff facing the sea. On the south the ridge of Worleberry is probably united beneath Loxton moor to the northern flank of the Mendip chain, since they dip towards one another in opposite directions: on the east, it seems to be connected with the southern flank of Broadfield Down, which is equidistant from the northern flank of the Mendip chain, and dips towards it, like Worleberry, at an angle of 45°. On the west, the low island of Breanback is a continuation of the same ridge, which probably reappears also in Flatholm †, a low level islet on the same line of bearing in the mid-channel. This islet consists entirely of mountain limestone; on the south-eastern side it presents cliffs about 40 feet high. The strata are saddle-shaped, and dip to the south on the southern side of the island, and to the north on the northern. The apex of the saddle is well marked in the eastern cliffs, but in the western the strata undulate considerably. On the north-east side is a small bay, covered with

* In the encampment, which crowns the western termination of this ridge, the multiplied lines of defence which traverse the hill on the land side, render it one of the most singular specimens of ancient fortification. The whole ridge is covered with traces of old inclosure and circular hollows.

† This island has been erroneously coloured in Mr. Greenough's Map as consisting of dolomitic conglomerate. It affords pasturage to a few sheep. There is a farm-house upon it, in the walled garden of which myrtles flourish in the open air; though the sea-breeze cuts off every tree in more exposed situations. There is a light-house on the highest ground at the southern point of the island.

shingle, in which are pebbles of chalk-flint, red sandstone, quartz, flinty slate, and porphyry.

The ridge of Woodspring is scarcely 100 feet in height; and dips, like Worleberry, to the south, and at an angle of 45°. The similar dip of these two parallel ridges is probably occasioned by a fault, similar to those which we noticed as occurring at Vobster.

A small patch of dolomitic conglomerate is laid against the eastern extremity of the hill of Woodspring, and the surface of the valley from thence to the ridge of Worleberry is occupied by a continuous bed of lias. The lias probably extends from Worle, beneath the marsh lands of Weston moor, to Uphill, Locking and Banwell; since at all these places it appears along the edge of the marshes. This marshy tract extends along the banks of the Yeo as far east as Congresbury. On approaching the western foot of Broadfield Down the limestone is skirted by a plain of red marl and newer red sandstone. Along the southern hangings of this down, the dolomitic conglomerate appears in great force, and in some instances (as at Red-hill, near Wrington, on the road from Bristol to Cross) ascends its flanks nearly to the summit. Detached summits of lias appear in this quarter.

Broadfield Down, the most southerly and the loftiest of the three groups mentioned in the introductory chapter as forming the western frontier of the coal-basin, occupies a triangular space, of which the three angles, on the north, the south-west, and the south-east, are marked by the villages of Barrow, Yatton, and Winford. The limestone strata dip in every part of it from the centre towards the circumference, and at angles varying from 5° to 50°. The lowest dip is at the south-west angle of the chain, where it points towards Worleberry.

The exact position of the south-eastern angle of this ridge is at a point called Heath Hill, about one mile south of Winford. Heath Hill consists of millstone-grit (resembling that of Brandon Hill above the town of Bristol) resting upon mountain limestone, and dipping to the south. There can be little doubt that if a trial for coal were made about a quarter of a mile to the south of this point, it would penetrate to the lowest of the coal-seams. Along the southern foot of the hill the beds of new red sandstone abut against the millstone-grit. On the further side of a valley, extending immediately to the west, are situated the ruddle-pits, for which this district is famous, and from which that mineral is exported to all parts of England. It is a highly ferruginous red ochre; is very abundant, and seems to occur in one of the lowest beds of the new red sandstone. Near Winford the lias sweeps over the intervening beds, and comes into immediate contact with the mountain limestone. It occupies nearly the whole extent of a long narrow valley, which is overhung at the eastern extremity by the picturesque and precipitous mountain-limestone crags of Hartcliff* rocks, and thence extends westward to the head of Brockley Combe.

The western side of Broadfield Down is the most elevated, and its declivity on that side is the boldest. The valleys which descend towards the west from the summit of the down, are terminated by gorges, resembling in appearance and structure, but on a smaller scale, that of Cheddar cliffs.

There is a small defile of this kind a little to the west of Barrow. Near the village of Brockley is a second of superior dimensions, extending nearly a mile from east to west, and exhibiting, especially on its northern side, abrupt precipices towering above luxuriant forest-trees. But the most magnificent is that of Cleve or Gobble Combe, extending from near the village of Cleve about $1\frac{1}{2}$ mile eastwards. The mouth of this defile is marked by a very striking conical hill, bearing on its summit a huge calcareous tor, and resembling Thorpe Cloud at the entrance of Dove-dale in Derbyshire. Like Brockley Combe, this ravine is most precipitous on the northern side, though on the southern there are occasionally some very bold cliffs. This chasm is inferior in magnificence to that of Cheddar only, but surpasses it in one feature, being clothed with luxuriant woods.

The second calcareous ridge belonging to the western frontier is that which, under the names of Leigh Down, Durdham Down, and King's Weston Down, is so well known in the neighbourhood of Clifton, where it is traversed by the deep and narrow defile of the Avon. These are the several portions of a calcareous zone encircling a nucleus of old red sandstone, which reaches from Portishead on the south-west to Westbury on the north-east.

Leigh Down is that part of the zone which extends from Clevedon on the Bristol Channel to the defile of the Avon at Clifton. It is not continuous with Broadfield Down, but is separated from it by the valley of Nailsea, which is occasioned by an undulation in the limestone strata, and contains a small coal-basin. The upper part of this valley, near Kencot Cross, is contracted to a narrow space, only $\frac{3}{4}$ of a mile broad, the substrata being concealed in that interval by overlying beds of red marl and lias. Leigh Down is about 11 miles long; its general line of bearing is from south-west to north-east, and the strata dip more or less accurately in every part of it to the south of their line of bearing, on an average at an angle of 30°, but, towards the west, at an angle of 60°. Its breadth, from being $\frac{1}{2}$ mile near Clevedon, increases to $1\frac{1}{2}$ mile at the de-

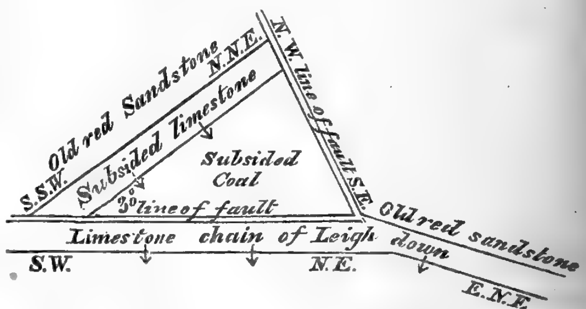
* Miscalled Hartley rocks in the Ordnance Survey; they give the name of Hart-cliff to the hundred in which they are situated.

file of the Avon. We will now trace this ridge in its progress eastward from the Bristol Channel.

The limestone of the detached hillock, whereon Clevedon church is built, dips to the S.S.E.; it presents a low cliff towards the sea. To this hillock succeeds a narrow flat, to the north of which the hills rise to the height of about 300 feet, and soon separate into two branches. That diverging to the N.N.E., and skirting the coast, is called towards the south, Walton Down, distinguished in the distance by the castle built on its highest point as an object from a neighbouring seat; to the north it is called Weston Down: of this branch we shall have occasion to speak in the sequel. That ranging to the eastward is the chain of Leigh Down. Near the point of divergence Leigh Down is completely broken through by a defile, along whose eastern brow the park of Sir A. Elton extends. On entering this defile from the south, we see the mountain limestone cropping out to the north, at an angle of 60°, from beneath the dolomitic conglomerate, and rising into steep and almost mural banks. The northern part of this ravine will be described hereafter. From Sir A. Elton's park to Wraxall the ridge is very narrow, and the dip of the limestone very regular, being a little to the east of south, at an angle of 60°. Towards the middle of this interval the ridge is traversed by two deep gullies, which, winding across it, include between them the insulated summit of Cadberry castle, crowned by Roman entrenchments. From this commanding position an excellent bird's-eye view may be obtained of all the ranges of the district. The chain is loftiest towards its centre above Failand's inn, where it is about 500 feet above the sea. Near Kencot Cross, the brook, which flows westwards from Flax-Bourton by Nailsea Moor to the Bristol Channel, quits the open valley that would seem to be its natural passage, and, taking a circuitous course, plunges into a rocky defile, cleft through a spur from Leigh Down. From Kencot Cross to the Avon, Leigh Down forms the border of the principal coal-basin: but the junction of the limestone with the coal-measures is very generally concealed by overlying beds of newer red sandstone and dolomitic conglomerate. On the southern hanging of the spur above noticed, where the road to Barrow branches off from that to Congresbury, the lowest of the coal-measures, the millstone-grit, of a hard and cherty character, may be seen reposing on the limestone. The same grit, similarly placed, constitutes the pointed summit conspicuous by its clump of trees above Ashton church. Here we may observe on the confines of the two formations the alternations of shale, grit, and limestone, which we have termed the upper limestone shale; and the same is continued behind Ashton Hall to the defile of the Avon close to Rownham ferry. Along this line, from Ashton to the Avon, the grit dips to the south-east, conformably to the limestone, at an angle of 45°.

Along the northern escarpment of Leigh Down we might expect to find the old red sandstone emerging from beneath the limestone; and such is the case throughout the eastern half of the chain from Portbury, where its section exhibits a perfect regularity of structure [see Plate XXXII. fig. 3.] to the Avon. Along this interval the old red sandstone is generally separated from the limestone by a slight valley, marking the course of the interposed shale. Near Charlton House, not far from Portbury, several abrupt, finely-wooded and picturesque valleys descend from the sandstone towards the north. The old red sandstone is here more than a mile in breadth; but near Abbot's Leigh, as you approach the Avon, the newer red sandstone and the dolomitic conglomerate come so near to the limestone, as to have only a narrow stripe of old red sandstone exposed.

The western half of the chain, from Clevedon to near Portbury, presents remarkable anomalies along its northern escarpment. The local phenomena are such, as clearly indicate that a great fault ranges along the edge of this part of the escarpment, affecting a very considerable subsidence of the strata; so that the coal-measures, depressed to the level of the old red sandstone, appear to occupy its place, and seem to dip beneath mountain limestone, on which in fact they repose. The limestone beneath the coal-measures having subsided as well as the coal-measures themselves, on re-emerging forms a second calcareous ridge, called Walton Down, to the west of Leigh Down, though not parallel to it. This is the ridge already mentioned, as diverging from Leigh Down near to Clevedon. The line of fault forms the third side of a triangular area, of which the two others are Leigh Down and Walton Down. It will be seen, on consulting the annexed sketch of the horizontal plan of the district, that the subsided mass having wheeled round through an arc of nearly 30°, has its eastern extremity thrown forward nearly 3 miles towards the north.



The anomalous appearances attending this fault are well exhibited in the northern part of the ravine traversing Leigh Down at Sir A. Elton's park. After passing the limestone, which bounds the ravine towards the south, the sides abruptly change to the Pennant coal-grit*, full of coaly matter, and

* A description of this coal-grit will be found in the sequel of this chapter.

dipping southward, in the same direction as the limestone, and apparently beneath it. Rocks of this coal-grit skirt the northern mouth of the ravine on both sides, where it opens into a marshy plain, extending between the principal and divergent ridges of limestone. [Plate XXXII. fig. 3. C.] On the western side of the ravine the mass of coal-grit rises up towards the limestone of Walton Down, upon the flank of which it evidently reposes in the manner shown in the sectional profile, Plate and figure last quoted. On neither side of the ravine is the fault marked by any irregularity of surface, the line of its occurrence being concealed by grassy slopes. To the east of the ravine the coal-grit occupies the escarpment of Leigh Down for the space of 4 miles, as far as the coal-mines of Clapton, beyond which it is concealed beneath the marshy plain. In this interval the stratification of the coal-measures is very much disturbed, but their general dip is southerly, towards the fault.

The point in the escarpment where the fault is arrested in its progress towards the east, and begins to run northwards, is about 1 mile east of the village of Clapton, about half way between two conspicuous villas, Naish-house and Charlton-house, situated on the brow of the ridge. A line of moist springy ground, and a deep swallet-hole near the summit of the escarpment, indicate the exact position of the fault, which crosses the road from Naish-house to Portbury at the distance of about half a mile from the point where the road branches off to Portishead. The coal-grit here abuts against the old red sandstone, which appears in its regular place beneath the mountain limestone on the eastern side of the fault. From this point the fault is probably continued in a northerly direction, beneath the marshy plain, to Portishead-bay on the Bristol Channel.

Walton Down, formed by the subsided mass of limestone, is divided along its summit, by a longitudinal valley, into two parallel crests, the southern consisting of mountain limestone, the northern of old red sandstone; an intermediate valley marking the shale that divides the two formations. This valley is occasionally flanked by precipitous rocks, particularly above the village of Walton, where a transverse valley intersects the ridge. The strata uniformly dip to the south-east, or towards the Clapton coal-field, at an angle of about 40°. The continuation of the limestone ridge is concealed, a little to the north of Weston-in-Gordano, by overlying masses of dolomitic conglomerate; but the ridge of sandstone extends about a mile further, until it reaches the southern extremity of Portishead-bay, where it terminates against the fault. The fault is indicated by contortions in the strata on the eastern side of the bay. The whole coast, from the bay of Clevedon to that of Portishead, is skirted by low cliffs of dolomitic conglomerate, which here forms a talus at the base of the hills of old red sandstone; the sandstone however is occasionally discovered supporting the conglomerate in the indentations of the coast. The northern side of Portishead-bay belonging, not to the subsided mass of strata, but to the return of the principal chain on the northern side of the nucleus of old red sandstone, will be described when we come to treat of that part of the calcareous border.

We now resume our account of the principal chain at that point where the celebrated defile of the Avon divides Leigh Down from Durdham Down. This natural section would require a full description, had not an excellent paper on the subject by Dr. Bright, and a detailed account of its strata by Mr. Cumberland, been already published in the Transactions of the Society. We shall therefore content ourselves with a few additional observations, which with the help of the Map and Sections, Pl. XXXIII. fig. 1 and 2, and Pl. XXXIV. fig. 1, we hope to render intelligible. Our remarks are chiefly directed to the right bank of the river, as being the best calculated for geological examination, the left bank being much less precipitous, and covered in great part with uxuriant woods.

The inclined strata, that crop out successively in this defile, are the millstone-grit, the upper limestone-shale, the mountain limestone, the lower limestone-shale, and the old red sandstone. The *millstone-grit* passes about 200 yards west of Rownham ferry, beneath the south-western extremity of Windsor terrace at its foundation, and immediately behind its gardens at the north-east end. Hence it may be traced to Clifton church, Brandon-hill, Park-street, St. Michael's hill, and the contiguous parts of Bristol. The lowest beds of this grit here consist of a red argillaceous sandstone.

The *upper limestone-shale,* consisting of alternating beds of shale, grit, and limestone, includes the first 5 strata of Dr. B. and the first 46 of Mr. C. It admits of the following 4 subdivisions.

	Thickness about
1. Upper limestone, having the usual characters of mountain limestone. It is the upper part of No. 1. of Dr. B., and its lower part is No. 1. of Mr. C.	20 feet.
2. Middle grit, consisting of shale and grit alternating, and having a thin coal-seam. It is included in No. 1 of Dr. B., and includes from No. 2 to No. 8 of Mr. C. It may be traced up the gulley beneath the wall of Windsor terrace gardens to the middle of Prince's Buildings.	60
3. Middle limestone, consisting of several beds having the character of mountain limestone.	

It includes the lower part of No. 1, and Nos. 2 and 3, of Dr. B., and from No. 9 to No. 31 of Mr. C. . Thickness about 60 feet.

4. Lower grit, consisting of shale and grit alternating, and having 2 thin coal-seams.

It includes Nos. 4, 5 and 6 of Dr. B., and from No. 32 to 46 of Mr. C. It appears behind the centre of the colonnade near the Hotwell-house, whence it ranges up the hill past the north end of Prince's Buildings, and the new Hotwell-house towards the south-side of the Mall.

The great deposit of *mountain limestone* is exhibited in the three succcessive cliffs of St. Vincent's rocks, the great quarry, and the black rock. The first limestone beds of this series (from No. 47 to No. 60 of Mr. C.) do not appear in the cliff of St. Vincent's rocks, but ascend a steep and grassy slope, in which Nos. 52 and 54 present conspicuous scars. The beds from No. 61 to No. 119 of Mr. C. occupy the face of a precipice, the middle of which is indented by a deep chasm. At the foot of this chasm, just below the crop of No. 114, the warm spring bursts out described by Mr. C. as beginning to flow in the months of March and April. An old quarry has been worked immediately beyond this chasm. On inspecting the section of the defile it will be seen, that from the Hotwells to this quarry the strata rise to the north-west at an angle gradually decreasing from 40° to 15°; and that in the quarry the inclination is even less than 15°; but that immediately beyond it the less inclined beds abut against others thrown up at an angle of 70°, and exhibiting a remarkable curvature in the upper part. The limestone cliff then terminates, and is succeeded by a steep, though not precipitous, bank, in which the strata close to the termination of the cliff are much confused and contorted. These signs of disturbance mark the occurrence of a great fault, to the north of which the strata have subsided to the depth of at least 130 fathoms, so that in the bank adjoining to the limestone cliff, we have a repetition of the entire series already traced from the fort of Windsor terrace to the Hotwells: viz. of the millstone-grit, of the 4 subdivisions of the upper limestone-shale, and lastly of the upper beds of the great mountain limestone. Of the occurrence of a fault there can be no doubt, since, had there been none, the millstone-grit and the upper beds of limestone-shale observed in the bank, must from their direction have been carried directly through the face of St. Vincent's rocks. The existence of this fault is also confirmed by the great horizontal distance that we find between the millstone-grit of St. Michael's-hill in the higher parts of Bristol to the east of Clifton, and the lower beds of mountain limestone at the western foot of Durdham Down near Westbury. This distance, as measured along a line perpendicular to the drift of the strata, amounts to 2 miles, and from the mean angle of dip, which exceeds 30°, we should obtain by calculation at least one mile for the entire thickness of the strata, if continuous. But this being considerably more than double of the known thickness of the mountain limestone in any other part of the district, the repetition of the series in consequence of a fault or faults is rendered highly probable. On the left bank of the Avon the fault may be traced up the gulley, which bounds the northernmost of the two Roman camps in Leigh Wood, ranging between Nightingale valley and the arch leading to Mr. Miles's park. The nature of the ground prevents our following it; but since it is nearly in the same line with the fault of the Clapton coal-field, it is not improbable that the two may be connected.

To return to the right bank. The millstone-grit crowns the scarry brow immediately below the northern rampart of the Roman camp, placed at the summit of St. Vincent's rocks, and extends thence to the turnpike. Below the turnpike the upper limestone presents a scar, at the foot of which a broad slope, following the direction of the strata, affords an easy descent to the river. A sort of double terrace succeeds, presenting a slight escarpment, in which a thin calcarous seam, the lowest probably of those of the upper limestone, is interposed between two of grit. The new road constructed in the face of the bank has afforded a complete section of the other strata of the Hotwell series, commencing with the lowest beds of the upper limestone. It begins near the foot of the bank in contorted strata of limestone interposed between contorted strata of grit, abutting against the fault. In pursuing the road the following are the strata which have been observed and accurately measured by Mr. De La Beche: they may be compared with the first 46 strata of Mr. C.'s section referred by us to the upper limestone, the middle grit, the middle limestone, and the lower grit of the upper limestone-shale.

	Ft.	In.	
1. Contorted bed of Limestone between contorted beds of Grit			Upper Limestone.
2. Beds of Marl of uncertain thickness			Middle Grit.
3. Rubbly Grit	3	6	
4. Green and red Marl	9	0	
5. Loose Grit	4	0	
6. Blueish, green, and red Marl	13	6	
7. Grit	4	6	
8. Grit	4	0	
9. Rubbly Grit	4	0	
10. Red Marl	4	0	
11. Rubbly Grit	3	0	

	Ft.	In.	
12. Rubbly Limestone	6	0	Middle Limestone.
13. Limestone	2	0	
14. Limestone	4	6	
15. Blueish Clay	0	6	
16. Oolitic Limestone, seeming to correspond to No. 12 of Mr. Cumberland	7	0	
17. Grit, thinning off	1	6	
18. Encrinal Limestone	1	4	
19. Limestone, thinning off	3	6	
20. Limestone	3	6	
21. Limestone	4	7	
22. Limestone, thinning off suddenly	4	0	
23. Limestone	1	4	
24. Limestone	4	3	
25. Limestone	2	6	
26. Red sandy Marl	0	6	
27. Limestone	2	9	
28. Limestone	5	10	
29. Limestone	2	10	
30. Rubbly compact Grit	10	0	Lower Grit.
31. Red Marl	1	2	
32. Greenish-blue Marl	2	8	
33. Red Marl	2	0	
34. Limestone	1	0	
35. Limestone	1	0	
36. Limestone	1	2	
37. Limestone	1	7	
38. Grit, thinning off suddenly	2	0	
39. Compact Grit	8	0	
40. Rubbly Marl	16	0	
41. Limestone	6	0	
42. Slaty Grit	8	0	
43. Limestone	1	8	
44. Marl	8	0	
45. Limestone	10	0	
46. Rubbly Marl . . about	30	0	

From the termination of this series to the corner where the road suddenly turns eastwards up a lateral defile (a distance of 80 paces), overlying beds of the dolomitic conglomerate occur, and from the road they ascend to the summit of the bank, forming a low cliff along the brow of this part of Durdham Down. From this brow they extend by Redlands to South-mead farm, $\frac{3}{4}$ of a mile west of Westbury, where lias comes in contact with mountain limestone, and crowns both it and the conglomerate with a ridge of greater elevation. The conglomerate, where the road down the bank intersects it, contains rounded masses of mountain limestone, sometimes of three tons weight. Hollow nodules of quartz, lined with quartz crystals, commonly called Bristol diamonds, and sometimes containing crystallized carbonate of lime and sulphate of strontia, are found, accompanied by hematitic iron ore, in the lowest part of the conglomerate; and this is probably the true geological position of these nodules, since they have been found in the greatest quantity to the north of St. Vincent's rocks, in digging the foundations of Harley-place, at the junction of the conglomerate with the limestone.

At the turn in the road above mentioned, the conglomerate is seen resting on thick beds of mountain limestone. These beds of limestone, extending from No. 142 to No. 158 of Mr. Cumberland, are seen on the towing-path cropping out from beneath the series observed in the bank, at the northern extremity of which they form a low precipice, separated by a narrow lateral defile from the lofty scar of the Great Quarry. The Great Quarry exhibits the beds from No. 159 to No. 196 of Mr. C. inclined at less than 30° to the horizon. If our views respecting the fault be correct, these must be considered as a repetition of the beds in St. Vincent's rocks. An interval of about half a mile, throughout which the bank, though steep, is not precipitous, exhibits the beds from No. 196 to No. 258 of Mr. C. At the beginning of this interval another warm spring gushes out, close to which the new Hotwell-house has been built.

The cliff of the Black rock commences at the end of this interval beyond a deep ravine winding up the bank, and includes from No. 259 to No. 291 of Mr. C. The angle of dip is between 40° and 45°. This cliff is succeeded by woody banks.

The length of the defile of the Avon, where it traverses the principal beds of mountain limestone, from St. Vincent's rock to the Black rock, exceeds $1\frac{1}{2}$ mile. It does not range exactly at right angles to the bearing of the strata, but a little to the north of it; so that its length is somewhat greater than that of a directly transverse line. Let us take the length of the latter at 1 mile, and the average angle of dip at 20°, which is below the truth. From these data we shall obtain $\frac{1}{3}$d of a mile as the aggregate thickness of the beds of mountain limestone in this quarter, a thickness far exceeding that which is deducible from the ordinary breadth of the calcareous zone, unless we admit the existence of a fault, and a partial repetition of the upper beds of the series.

The *lower limestone-shale* consists of beds of shale alternating in the upper part with beds of limestone, and in the lower part with beds of sandstone. The aggregate thickness of these beds is here 500 feet. The beds of limestone are Nos. 292, 293 and 294 of Mr. C., the lowest of which is a well-characterised red encrinal limestone, forming a conspicuous band on the ascent of the woody bank to the south of Cook's Folly, and one equally distinct on the left bank of the river.

The *old red sandstone* not being exposed to any extent in the face of the cliffs, cannot be so well examined as the limestone. It may best be studied on the left bank of the river, where the towing-path ascends over a steep rise. We have there observed the outcrop from beneath the shale of the following beds. 1. Red sandstone and marl; 2. grayish marly sandstone; 3. red marly sand and variegated sandstone; 4. thick strata of quartzose conglomerate; 5. red gritty sandstone. Dr. Bright mentions vegetable impressions and traces of coal as occurring near the top of the series, and a bed of calcareous concretions, of the nature of the Herefordshire cornstone, near its middle.

As the defile opens, at Sneyd park on the right bank of the river, and in the corresponding hill on the left, the old red sandstone is overlaid by horizontal strata of dolomitic conglomeraie. The junction of the two formations on the left bank is represented in Plate XXXV. fig. 1. The sandstone rises again to the surface, and is displayed in the face of a precipitous bank near the Powder Magazine below Lord de Clifford's park; but, with this exception, the conglomerate occupies both sides of the river, until it sinks below the marshes that border on the Severn.

We shall now pursue the calcareous chain on the right bank of the Avon, and trace its return on the opposite side of the nucleus of old red sandstone. The district occupied by this nucleus, and overlaid for the most part by the conglomerate, comprehends a triangular space inclosed between the Avon from Cook's Folly to the Powder Magazine, and lines drawn from these two extremities of the base of the triangle to its apex at the village of Westbury. The fundamental rock is laid open by denudation along the brook to the north of Sneyd park, and in the bed of the Trim rivulet, where it issues from the ravine of Blaze Castle close to the water-mill: but near to Westbury the conglomerate comes in contact with the mountain limestone. The calcareous zone ranges round this area, presenting towards it a steep escarpment. From the defile of the Avon to Westbury it is known by the name of Durdham Down; its strata dip to the south-east at an angle of 30°. The northern part of the zone is called Brinterry Hill: the strata here dip northwards, and are nearly vertical; and the ridge in consequence becomes much narrower than before. The southern extremity of Brinterry Hill, called Gorham's Chair, is separated by a deep and precipitous ravine from the prolongation of the calcareous zone, which receives the name of King's-Weston Down. The hill on which Blaze Castle stands, borders this ravine on the south-west, and being cut off by another defile from King's-Weston Down, presents a remarkable insulated summit. The position is strengthened by ancient entrenchments. The Trim, which rises without the calcareous chain, avails itself of the breach of Blaze Castle to flow through the chain, and thence to pass through the internal area into the Avon. Were a dam of inconsiderable height to be constructed across the ravine, the brook would find its way through the mouth of the broad valley, in which it rises, into the marshes of the Severn.

King's-Weston Down ranges W.S.W, through Lord de Clifford's park, until it terminates at Penpole-point, being bounded by the marshes. The strata are highly elevated, and dip W.N.W. To the west of the road, at the western foot of the down, are some limestone quarries, in which the dip appears to be almost inverted. The whole of this ridge is skirted along its outer flank by the overlying deposits, which we before traced over Durdham Down to the west of the village of Westbury. From Penpole-point the limestone ridge points exactly to Portishead-point, on the south of the confluence of the Avon with the Severn; and on examination the strata at that point are found to consist of mountain limestone mantling round the central nucleus of old red sandstone. The limestone may be traced from the northern extremity of Portishead-point, ranging in a southerly direction along the summit of a woody hill, to the old Battery commanding Portishead-bay. In the north-eastern angle of the bay the lower strata of the limestone, here approaching to the fault of the Clapton coal-field, are bent into zig-zag curves. On the south-east the old red sandstone emerges from beneath the limestone, and forms an almost insulated hill between the village of Portishead and the limestone. On the north-west along the coast, particularly near to Portishead-point, a covering of dolomitic conglomerate greatly conceals the inclined strata, which are displayed, at intervals only, in low cliffs. At low-water, however, we discover the Pennant coal-grit reposing against the calcareous chain, and may trace it nearly all the way from Portishead-point to the fort; and in the cliffs of a small cove, half way between the northern cape and the fort, the crop of a bed of coal is seen, having a roof of the Pennant abounding in vegetable remains. These strata are highly elevated, and occasionally vertical or even reversed in their dip. [See Pl. XXXII. fig. 3.] These coal-measures seem to indicate the existence of a yet unexplored coal-basin in the valley of the Severn between the calcareous chain now treated of, and that of Monmouthshire. The limestone rock, called the Denny, in the mid-channel opposite the mouth of the Avon, is situated exactly in the line which would connect the two calcareous chains. The strata, however, are nearly parallel to those at Portishead, dipping N.W. at an angle of 60.

We now proceed to describe the third calcareous ridge of the western frontier. It will be seen in the Map that the lias, skirting round Brinterry-hill, overlies the northern prolongation of Durdham Down. A continuity of elevation is thus maintained through an interval of more than two miles between Henbury and Almondsbury, over the depressed beds of limestone, which are seen on either side dipping towards one another along the line of submersion beneath the superstrata. The limestone re-emerges from beneath the red marl and lias in the hillock upon which stands Over House, and thence it stretches in a north-north-easterly direction. The lias, however, continues to overtop the limestone as far as the brow which gives name to the ancient mansion of Knoll. This is crowned by a cap of lias, cliffs of mountain limestone sweeping round its base. From this point the limestone passes through Almondsbury, where it dips to the S.E., and is nearly vertical, and thence forms a distinct range along which the road from Bristol to Gloucester proceeds. Near the inn called Alveston Ship, this range inosculates with Alveston Down, a part of the calcareous zone which protrudes westwards, and appears to mantle round a nucleus of old red sandstone. A gritty sandstone, apparently of that formation, may be observed on the north of the common marked by the windmill above Olveston, and the old red sandstone undoubtedly appears at the northern foot of this range close to the hamlet of Kingston; and though difficult to trace, owing to inclosures and the inaccuracy of the Maps of the district, it is probably continuous with the sandstone that occurs at the point first mentioned. On the west the limestone dips from this central axis of sandstone towards the villages of Olveston and Elberton, and on the south-east towards Tockington. The brow of the hill towards Kingston has a hanging mass of lias and red marl abutting against mountain limestone; and two or three detached summits between Littleton and Elberton, on the principal of which is an extensive Roman camp, consisting of these overlying formations.

The chain of Olveston Down is separated from the Severn by an interval of more than 2 miles, in which the overlying deposits prevail. The mountain limestone, however, may be seen in the bed of the Severn at the base of Aust Cliff during low water, bearing across the river in a westerly direction for a small insulated crag at the mouth of the Wye, belonging to the same formation, called Chapel-rock; and thus the mountain limestone of the basin of Bristol becomes united to the chains of mountain limestone in Monmouthshire.

It is probable that the axis of old red sandstone, which we traced from Portishead to Westbury, continues to range northwards along the foot of Almondsbury Down, though concealed by overlying superstrata and a tract of marsh-land. To the west of this axis, beneath the marsh-lands of the Severn, the coal-measures seen at Portishead-point may be expected to be prolonged. The exterior limestone chains of this unexplored coal-basin appear to be Portishead-hill, Kingsweston Down, Olveston Down, Aust Cliff, Chapel Rock, the Monmouthshire chain from thence to the village of Undy, and the Denny Rock opposite to Portishead.

From Olveston Down the frontier of limestone and old red sandstone sweeps near Thornbury to Tortworth, where it reaches its northern apex. On the edge of the Coal-basin at Cromehall near Tortworth, at the junction of the mountain limestone with the incumbent millstone grit, we find an alternation of the beds of grit and limestone, very similar to that which at the defile of the Avon we have described as the upper limestone-shale. The grit, however, in this instance assumes the form of a quartzose conglomerate, agreeing in character with the rock which on the north of Merthyr Tydvil, in South Wales, supports the coal-measures. The strata dip at an angle of 35° to the south.

We had formerly devoted a chapter expressly to the district immediately north of Tortworth; but finding that a detailed account of the northern angle of the basin has since been presented to the Society by a geologist, who to talent of a high order adds the advantages of local residence, we determined to suppress our own more rapid sketch. We wish only to express one opinion respecting the rocks of that district.

Two masses of amygdaloidal trap, about 2 miles long, are there found traversing the transition limestone and the old red sandstone, which from their general parallelism to one another and to the strata which bound them, might appear at first sight to be regular *beds*. We are of opinion, however, after a careful examination of their course, that they really are portions of *dykes* irregularly traversing the other rocks. The thinness of these masses at their eastern extremity contrasted with their thickness on the west towards Woodford-green, and more especially the mode in which at the latter place they penetrate among and entangle fragments of the contiguous coralliferous limestone, which have been altered by the contact;—these are the circumstances which have induced us to form this opinion concerning their nature.

3. On the eastern frontier of the Coal-basin.

At Tortworth the exterior chain is deflected somewhat suddenly to the S.E., extending in that direction through Wickwar to Sodbury. It presents a low chain of mountain limestone with old red sandstone along its outer border. The junction of the two rocks may be seen at Wickwar, the church being built upon the sandstone. Overlying red marl abuts against the foot of the sandstone escarpment, and just below the church of Wickwar a cap of lias also rests upon the sandstone slope. To the east of Wickwar, on the other side of a narrow valley, lias forms a broad terrace, above which rises the lofty oolitic ridge of the Cotswold. To the south of Sodbury the exterior chain becomes so low, that the lias terrace extends over it, and passes within the basin. The calcareous limits of the basin, however, are exposed in valleys of denudation between Sodbury and the Avon at three points lying due south of each other, and in the line of prolongation of the exterior chain, viz. 1. At Codrington Court; 2. At Wick Rocks; 3. At Granham Rocks Of these Wick Rocks alone require particular notice. Hills of lias here surround the valley of the Buoyd on the east, north, and west. That brook here deserts the broad valley to the east of the rocks, in order to traverse a narrow defile ¾ of a mile in length. At the northern extremity of the defile we meet first with old red sandstone; then with lofty precipices of mountain limestone, crowned with ancient entrenchments defending the opposite sides of the pass; and further on, before we issue through the southern gorge, we see the millstone grit resting against the limestone. Beyond the grit, horizontal dolomitic conglomerate lines the mouth of the valley. All the inclined strata dip due west at an angle of 70°.

At Beach Lane and Granham Rocks, a little to the south of Tracy-park, the mountain limestone is just seen in the bottom of the valleys excavated through the lias. The millstone grit is also seen at the latter spot. In the wide interval between the Avon and the Mendip Hills the limestone frontier is entirely concealed by overlying deposits.

On the Coal-measures of the Basin.

The coal-measures appear to be distributed throughout the greater part of the area included within the outer calcareous ridges of the basin, though concealed in many places by the overlying formations. It seems probable that these later formations were at one time much more extensive than at present, and that they have been furrowed out and removed in those places where the coal-measures are now exposed. These uncovered areas I shall term the Northern, the Central, the Southern, the Eastern, and the Western Coal-tracts.

The *Northern* Coal-tract, which is the most extensive and elevated, comprehends the collieries of Iron Acton, Sodbury, and Kingswood. It extends in length nearly 12 miles, from the northern apex of the basin at Cromehall near Tortworth to the village of Brislington, on the left bank of the Avon, near Bristol. Its breadth from east to west, in the parallel of Sodbury, where it is the greatest, is nearly 4 miles. The coal-measures are exposed in immediate contact with the limestone along the northern limits of the basin from Sodbury to Cromehall and Titherington; but on the western, southern, and great part of the eastern border of the tract, they are skirted by hills of red marl capped by lias, through both of which formations, at Pucklechurch on the eastern border, shafts are sunk to the coal. To the south of this coal tract, at Brislington, the red marl and lias form a table-land, supporting the loftier oolitic summit of Dundry-hill.

The *Central* Coal-tract commences on the south of Dundry-hill and of the table-land of lias, at the foot of their descent towards the vale of the Chew river. It consists of two portions connected by a narrow valley: the northern extends in length about 6 miles, from Burnet on the north-east towards Knowlhill near Stanton Drew on the south-west, and is about 2 miles broad near Pensford. The southern portion extends about 3 miles, from Temple Cloud on the west to between High Littleton and Timsbury on the east. Both these portions and the valley connecting them, are bounded by ranges, which towards their bases consist of red marl, but are capped towards their summits by lias, bearing occasionally still higher platforms of inferior oolite.

To the south-east of this central coal-tract, through an interval of 6 miles, the coal-measures are entirely concealed by the overlying deposits. Throughout the whole of this interval, however, every valley abounds with shafts, which are sunk through the red marl into the coal-measures; and many are begun on the summits of the platforms of lias. Of the latter kind several occur in the parishes of Timsbury and Paulton; but the deepest is on Clan Down near Radstock, which begins in the upper part of the lias, close to its junction with the inferior oolite, and is sunk 200 fathoms before its horizontal adits begin to be thrown out. On the edge of the same down, towards Paulton, is a shaft which begins in the oolite, but is much less deep than the former; the coal-seams, owing to a rise of the strata in this direction, here approaching much nearer to the surface. As we approach the Mendip Hills, the coal-measures are denuded to the extent of about an acre on the ascent of the hill above Chilcompton, on the road to Midsummer Norton; and at length are again exposed in the *southern* coal-tract, which extends from west to east nearly 6 miles, beginning a little below the point where the Nettlebridge stream is crossed by the road from Bath to Shepton-Mallet, and ending between Vobster and Mells. Its greatest breadth is about $2\frac{1}{2}$ miles, in the meridian of Holcombe. On the south the coal measures occasionally cross the Nettlebridge stream, to rest against the calcareous chain of the Mendips: on the north the inferior oolite comes in contact with them, along a somewhat elevated table-land from Holcombe to Mells. At either extremity the dolomitic conglomerate closes over them, on the east forming cliffs overhanging the river from Vobster to Mells-park, on the west crowning with precipitous scars the ravine through which the same river issues between Stratton-on-the-fosse and Ashwick.

The *Eastern* Coal-tract is laid open in the Golden Valley, or Vale of the Buoyd, at Wick and Upton, and in the course of the brook falling into the Buoyd from Tracey-park; and at Newton St. Leo, on the left bank of the Avon below Bath, the coal-measures are again displayed, dipping towards the interior of the basin.

The denudations of Wick and Tracey-park show the millstone grit incumbent on the mountain limestone; and several coal-seams are laid open and worked at Upton and Newton. The eastern tract is encircled by dolomitic conglomerate, newer red sandstone and lias.

The *Western* Coal-tract lies at the south-eastern foot of Leigh Down near Bristol. The strata bordering on the millstone-grit are the only coal-measures that are exposed on the surface; and we have already traced their longitudinal extent from Kencot-cross to Rownham-ferry and the upper part of Bristol in treating of Leigh Down and the defile of the Avon. These coal-measures are bounded on the east by overlying beds of red marl, which form the upper strata in the shafts of all the coal-pits between Long-Ashton and Bedminster.

The coal-field of Nailsea may be regarded as a continuation of this western tract. The fragments of strata of newer red sandstone that hang on the slopes of Leigh and Broadfield Downs to the north-west and south-east of this basin, show that the exposure of the coal-measures is here the result of denudation. The subsided coal-tract of Clapton has already been noticed.

In order to obtain a connected view of the distribution of the coal-measures throughout the basin, it is necessary to observe that, by a great undulation in the strata*, the lowest of the coal-measures are thrown up at very high inclinations into a saddle-shaped ridge, extending through Kingswood across the basin from east to west, and subdividing it into two partial troughs;—one on the north of the ridge, having its centre in Coal-pit Heath, to the east of the Engine-pit at Bitterwell, and extending to the limestone at Cromehall; the

* The elevation of this ridge and the faults of St. Vincent's Rock and of the Clapton coal-field are very possibly the result of the same convulsion; since the disturbances appear on the continuation of nearly the same line.

other on the south of the ridge, having its centre at Radford, and extending to the limestone of the Mendips. The northern trough is of much less extent than the southern, including only the northern part of the northern denuded coal-tract: the southern trough embraces as well the southern part of the northern coal-tract as the whole of the central and southern.

The principal and most permanent subdivisions of the coal-measures that we have been able to trace in this basin are the following, beginning with the lowest.

1. The *Millstone-grit*; 2. the *Lower coal-shale*; 3. the *Pennant grit*; 4. the *Upper coal-shale*. There is also another coal-grit, occurring between Compton Dando and Pensford, whose relations are equivocal, but which occupies a place perhaps above the upper coal-shale.

1. The *millstone-grit** agrees in position and seems to be of cotemporaneous origin with the millstone-grit of Derbyshire. It differs however from the grit of Derbyshire and the North of England in being highly charged with red oxide of iron, and so compact as often to assume the character of a close-grained cherty quartz-rock. In these respects it agrees with the lowest member of the Warwickshire coal-field between Atherstone and Nuneaton.

The character of this grit is well exhibited in Brandon-hill above Bristol, the rock at which place may be taken as the type of its general appearance in the Bristol coal-basin. It has been described by Dr. Bright in the 4th volume of the Geological Transactions, under the name of ferruginous sand and siliceous ironstone; but it may be doubted whether the author has sufficiently distinguished the millstone-grit of Brandon-hill from an overlying conglomerate resting against its southern slope, and belonging to the new red sandstone. This conglomerate is much more highly ferruginous than the millstone-grit itself.

Associated with the compact and cherty beds of this grit, there often occurs a siliceous conglomerate containing large quartzose pebbles. This might be applied, as it is in the Forest of Dean, to the fabrication of millstones. The beds of grit are divided by way-bands†, and often by thick seams, of red ferruginous clay. The lower beds of grit contain impressions of the shells, the *Anomia producta* for instance, which usually occur in the mountain limestone, and also impressions of those vegetables which are commonly found in the coal-measures. The alternating beds of grit, shale with coal-seams, and limestone, observed at the junction of the millstone-grit with the mountain limestone, have already been described under the title of the *Upper limestone-shale*.

* The term "*millstone*" is applied by the miners in this district to the dolomitic conglomerate.

† These waybands of clay render the highly inclined masses of grit, which skirt Brandon-hill, a very insecure foundation for buildings, since after frosty seasons the upper strata are disposed, if overloaded, to slide over the inclined planes presented by the loosened argillaceous beds.

The millstone-grit may be seen at the following places, either in the Kingswood ridge or along the borders of the coal-basin. In the northern coal-tract at Cromehall it reposes on alternating beds of grit and limestone, dipping southwards at an angle of 35°; and hence it stretches towards Titherington, though concealed at the latter place by overlying beds of lias. Still further to the south it is found resting against mountain limestone in Knoll-park near Almondsbury. Between Sodbury and Yate it may be seen on the road-side. On the borders of the eastern and western coal-tracts its position has already been described; on those of the southern it every where intervenes between the other coal-measures and the limestone, lying parallel to the latter, and being nearly vertical. It here frequently contains beds of the most decided conglomerate. It appears also as a quartzose conglomerate between the coal and limestone along the northern frontier of the small coal-basin of Nailsea, and may be traced over Nailsea-heath, a long slip of swampy ground lying north of the village. It is the lowest of the beds exhibited in the saddle of Kingswood, and may be studied in the quarries on the north side of the new church of Kingswood, where it dips rapidly to the north. An axis of this rock probably exists near the surface along the whole diameter of the elevated plain of Kingswood. The saddle is said by the most intelligent miners to abound with contortions and undulations.

2. The *Lower coal-shale,* which reposes on the millstone-grit, consists principally of argillaceous strata, even the grit, which alternates with the shale, containing much clay, and occasionally resembling some of the varieties of grey-wacké. Slate-clay predominates, and imparts its character to the whole series. This, when very fissile, is called by the miners, on account of its easy *cleavage,* "*cliff*" or "*clives*;" but when compact, and less disposed to cleave, it is called "*duns,*" a word obviously of the same origin as the German "*thon.*" Ironstone occurs in some of the lower beds of shale. Vegetable remains, particularly those of long-fluted reeds, and of trunks marked on their exterior by lozenge-shaped impressions, are common; but those of ferns are less so than in the upper coal-shale.

The coal-seams are improperly called *veins* by the miners throughout the Bristol coal-basin. Many seams belong to this lower series; but no permanent distinctions have been ascertained between those of the upper and lower coal-shale; and it is only by their position in relation to the Pennant coal-grit that we are able to distinguish them.

In the northern part of the northern coal-tract two sets of coal-seams have been ascertained to exist between the millstone and Pennant grits; those of Cromehall, which contain three seams, and those of Yate, which contain four.

For the particulars of these workings we must refer to Mr. Weaver's paper. The collieries of Pucklechurch (see 1st Coal-section), which are worked by shafts through the lias and red marl, appear from their position in the basin to belong to the lower coal-shale, and to connect the coal-seams of Yate with those on the north of Kingswood. The coal-seams on the northern side of the saddle of Kingswood dip rapidly to the north. They are subdivided by the miners according to the collieries in which they are worked, of which the Soundwell*, the Staple-hill, the Duke of Beaufort's, and those near Fishponds are the principal. (See 2d Coal-section.) One of the chief and uppermost seams, called the Cock vein, may be traced from the south of Mangotsfield to the south-west of Fishponds, closely bounded on the north by the superjacent Pennant grit.

In that part of the northern coal-tract which lies on the south side of the saddle of Kingswood, a series of beds is worked beneath the Pennant grit, which skirts the Avon from Keynsham to Bristol, along a line passing through Haul-lane, Hanham, St. George's, Crews-hole, and Pyle-marsh. These beds dip rapidly to the south from the ridge of Kingswood. (See 3d Coal-section.) The miners have not attempted to identify the coal-seams on the northern and southern flanks of Kingswood, though their general correspondence is obvious from their being both included between the millstone and Pennant grits.

The lowest of the Hanham seams have also been worked at Whitehall, and near the foot of Lawrence-hill on the north-eastern suburb of Bristol. (See 4th Coal-section.) Other seams are worked immediately below those of Whitehall, at Easton. (See 5th Coal-section). They dip towards the south-east, and range in an east-north-easterly direction towards the Lodge collieries, and in a south-westerly direction by the eastern suburbs of Bristol directly towards the collieries of Bedminster. (See 6th Coal-section.)

The collieries of Bedminster in the western coal-tract are thus obviously referable to the lower coal-shale. The Ashton seams, now out of working, lie below those of Bedminster; they both rise conformably against the millstone-grit of Leigh Down. (See 7th Coal-section.) In the coal-field of Nailsea, the lower seams, alternating with shale, are interposed between the millstone and Pennant grits. (See 9th Coal-section.)

In the eastern coal-tract the collieries of the Golden Valley between Wick-rocks and Bitton are worked in seams immediately below the Pennant grit, which are said to be the same as those of Hanham and the collieries to the south of Kingswood. Those of Newton St. Leo are considered by the miners

* The Soundwell collieries are remarkable for affording a very copious spring of brine.

as agreeing with those of the Golden Valley. A great fault, ranging east and west to the north of Bitton, affects as well the overlying strata as the coal-measures. It cuts off the collieries of the Golden Valley which lie to the north of it, and passing over the southern extremity of Bitton Hill, an eminence of red marl capped by lias, throws down the beds to the south of it at least 200 feet; so that the inferior oolite abuts against the lias and subjacent red marl, which are to the north of it, and the lias has sunk to a level with the plain below. [See Pl. XXXII. fig. 2. B.] To the west of Bitton Hill, and a little to the east of Oldlands Chapel, the lias is thrown down to the foot of the escarpment of red marl, and abuts against the coal-measures; and from the east of Oldlands Chapel to Hanham and the Avon, on the prolongation of the line of fault, the junction of the lias with the coal-formation is abrupt, and the rocks continue subject to great disturbances. This fault is an exception to the general rule, that faults are confined to the inclined strata, and do not extend upwards to the overlying ones. Other instances of the same kind will be noticed in the sequel.

In the southern coal-tract the coal-seams, though thin, are numerous, 31 being distinctly recognised near Nettlebridge. These may be divided into a northern and southern series. The southern and lowest series is worked along the whole length of the Nettlebridge valley from Emborrow to Mells, and is distinguished by two principal seams, the lower called Perrink, the upper Callows*. (See 16th and 17th Coal-sections.) The drift of these seams from Vobster to Ashwick is E.N.E. and W.S.W.; but between Ashwick and Moorwood it bears suddenly towards the north, conforming throughout to the drift and flexure of the limestone of the Mendip chain. The northern and upper series of coal-seams is worked along a line parallel to that of the southern series and about ¾ths of a mile to the north of it. The principal seam is called the Garden course. (See the Coal-sections from 10 to 15.) The whole of this southern coal-tract, since it is bounded on the south by the millstone grit, which is interposed between the Mendip limestone and the coal-measures, and on the north by the Pennant grit, which ranges through Holcombe and has lately been pierced in a shaft between Chilcompton and Stratton, must undoubtedly be referred to the lower coal-shale. Both the northern and southern coal-seams present phenomena of the highest geological importance.

In the meridian of Pitcot, situate a little to the north-east of Nettlebridge, all the strata are vertical, a perpendicular shaft being there sunk in a single bed of coal to the depth of 80 fathoms. To the west of this meridian the strata dip at high angles to the north and north-east, conformably to the limestone;

* Most of these seams at Vobster afford good smith's coal.

but to the east of this meridian as far as Mells they dip to the south, appearing to sink beneath the great substratum of limestone; so that they have been turned over and thrown backwards, and often to such a degree, as to lie more than 45° to the north of the vertical line. This inversion of dip extends through a tract 4 miles long, and is proved in more than ten distinct collieries; and the consequence of it is, that those seams which lie the highest in the shafts to the west of Pitcot are found the lowest in the shafts to the east of that place.

These changes of dip are frequently attended with contortions as abrupt and striking as those in the primitive slate rocks, especially in the southern series of beds, which are often broken and twisted most capriciously. At Bilborough colliery in Vobster the flexures are so great as to twist the strata like the letter Z, so that the same coal-seam is thrice cut through by the same perpendicular shaft; and it is a common occurrence in this line of collieries for this to happen twice. In the adjacent limestone of the Mendips the strata though highly inclined, and often vertical, are generally plane and parallel, and the millstone grit usually conforms in this respect to the limestone; the contortions being confined to the softer argillaceous strata, as is the case in the isle of Purbeck on the coast of Dorsetshire [see Mr. Webster's representation and account of these contorted strata in Sir H. Englefield's work on the Isle of Wight]. We have already noticed, in our account of the Mendip chain, the occurrence of two parallel faults near Vobster, which cause the limestone with its superjacent coal-measures to trap up twice in succession. The lesser faults of this district cannot so easily be traced, in consequence of their number and complication, and of the convolutions to which the whole mass of strata is subject.

In the Clapton coal-field, we cannot pronounce decisively to which division of the coal-measures the seams of the subsided mass belong; the workings having been so long disused that we have not been able to procure any account of them. We are inclined however to refer them to the lower coal-shale.

3. *The Pennant grit* consists of thick stratified masses of very fissile sandstone, having mica, decayed felspar, and carbonaceous vegetable fragments abundantly disseminated through it, and varying in colour from greenish gray to dark brick-red. The thick beds of grit alternate with thin strata of shale and coal. It is known by the name of Pennant stone, and is quarried largely for paving and building throughout the district*. The total thickness of this series cannot be less than four or five hundred feet; and is very possibly greater.

The Pennant forms a zone around the upper coal-shale within the troughs on either side of Kingswood. In the northern trough it circles around Coalpit-

* All the hard and fissile coal-grits are indiscriminately called Pennant by the miners.

heath, forming a broad band through the parishes of Iron Acton, Winterbourn, Stoke, Mangotsfield and Westerleigh *. On the south-east of Winterbourn it rises into some broken hills, conspicuous in a country for the most part tame and flat; and along the course of the river Frome below Winterbourn, as far as Frenchhay and Fishponds, it constitutes a defile, which occasionally assumes a picturesque character. Along the southern edge of this zone, where the Pennant rests on the basset of that coal-seam in the lower shale, called the Cock-vein, it dips very rapidly to the north and north-west. This may be particularly observed in the defile of the Frome to the south-west of Fishponds; but on the opposite side of the river near Frenchhay, it rises at a very low angle in an opposite direction; that is, towards the limestone, which between Henbury and Almondsbury forms the boundary of the coal-field; though here the interval between the Pennant and the limestone is concealed by red marl and lias. It appears from the dip of the strata at Stoke and Mangotsfield, that on approaching the ridge of Kingswood they are bent round it in the manner represented in the annexed figure.

In all other parts of the zone, the Pennant dips towards the centre of the northern trough in Coal-pit heath, and usually at a considerable angle. To the north and south of this zone, the lower coal-shale, as has been already stated, may be traced beneath the Pennant; but it is concealed to the east and west by the red marl and lias, which overlie the exterior edge of the Pennant; the shale however seems to have been proved at Pucklechurch beneath these horizontal deposits.

The zone of Pennant that encircles the upper coal-shale in the trough to the south of Kingswood, is only very partially exposed. It is defined most clearly along the banks of the Avon between Keynsham and Bristol, where it forms a tract about three miles broad, traversed by a defile of that river and by the precipitous valleys of some tributary streams. This elevated tract is separated from the platforms of red marl and lias to the south of it by a broad valley, raised about 50 feet above the level of the Avon at Keynsham, through which the intended continuation of the Kennet and Avon canal was to have passed. This valley appears at a little distance to be the only outlet through which the

* At Oatley, to the S.W. of Westerleigh, a quarry of the Pennant is wrought for stone-tile.

Avon can escape from the plain of Keynsham; the river however suddenly winds round a little knoll, marked by a farm-house called the Lodge, and plunges itself into a narrow and concealed defile *, from which, after a course of 3 miles, it emerges into the plain of Bristol, shortly afterwards to be again engulfed in the defile of Clifton. The cliffs bounding this defile are about 100 feet in height, and along the greater part of its extent mantled with wood. At one point, where the river bends rapidly round a long peninsula, the scene presented is of great beauty.

Near to this point the Brislington brook flows into the Avon from the south, after passing through a ravine of similar character. It rises from the side of Dundry-hill at the junction of the inferior oolite with the lias, and having traversed the platform of lias, crosses on the south of Brislington the broad valley which separates that platform from the Pennant. Its more obvious course would have been westward, along this valley, into the plain of Bristol; and a dam of no great height would still force it in that direction; but it plunges into a deep chasm excavated through the ridge of Pennant, and by this channel seeks the Avon.

The extension of this ridge of Pennant to the east and west is concealed by the overlying formations. On the west the red marl extends from St. George's to the plain of Bristol: and on the east, near Hanham, higher grounds of red marl capped by lias cover this coal-grit. At the entrance into the defile of the Avon from the plain of Keynsham, the transition from lias to the Pennant is so abrupt as probably to be occasioned by a fault, which has brought the lias down to its present level, which is that of the subsided mass of lias at Bitton; and to a similar cause we may ascribe the rapid eastern dip of the lias in the cliff which here skirts the northern bank of the river. Similar disturbances attend the junction of the Pennant and lias on the ascent of the hill connected with this cliff on the upper road from Bath to Bristol; and they are still more strikingly displayed on the east of Oldlands Chapel, when we come close to the line of the fault extending from the Golden Valley across Bitton-hill.

The Pennant is again exposed in the vale of the Buoyd, about half a mile above Bitton, to the east of the ridge of lias which caps Bitton-hill, and to the north of the fault of the Golden Valley. It is also found on the continuation of the same line reposing on the lower coal-shale in the Newton collieries. The dip of the Pennant, along the line through which we have traced it from the plain of Bristol to Newton, is generally to the south-west; on the north it is bounded by the lower coal-shale; on the south, in the village of Brislington, it supports the upper coal-shale.

* The entrance of the defile near the Lodge has been strengthened by an ancient *agger*.

From St. George's the zone of Pennant, bounded on the west by the lower coal-shale of the collieries of Bedminster, must range beneath the lias platform that supports Dundry-hill; its inner border seems to be indicated by a line of coal-seams passing from Brislington* through Queen's Charlton to Burnet, where the lowest seam is described as being covered by a stratum of Pennant 20 feet thick. A notice of these workings is preserved in a memoir by Mr. Strachey, printed in the Philosophical Transactions for 1719; and from the sites of the old workings mentioned in the memoir, or to be traced on the spot, the drift of the seams must be from N.W. to S.E., and their dip therefore to the N.E.

On the northern border of the central coal-tract, a little to the south of Burnet, and at Compton Dando, we find a coal-grit, of an equivocal character, resembling the Pennant; which grit is seen also between Compton Dando and Publow, on the lower hill beneath the escarpment of red marl and lias, and at the foot of the same escarpment between Whitchurch and Pensford, on the road from Bristol to Wells. Its dip at these points seems to be S.W. The Pennant certainly appears dipping south about a mile to the S.W. of Stanton Drew church, on the road to Stowey. To the south of this point a range of lias overlies and conceals it; but on the other side of that range it emerges in Temple Cloud hill to the south of Clutton, and thence ranges eastward in a line of pointed knolls to the south of Littleton. One of these knolls, called Highbury-hill, is crowned with an ancient encampment; and at its base, a brook forms a picturesque cascade, falling from a height of about 30 feet. In this spot we see very strikingly instanced the effect produced on the character of the scenery by the nature and inclination of the strata. The lofty ranges of horizontal lias bounding the valley are flat and tame; while the lower ridge of Pennant is abrupt, wild, and varied. The dip is here north-east, at an angle of 30°.

The Pennant, after being concealed to the south of Highbury-hill by the overlying strata, appears in a small patch, formerly mentioned, on the ascent of the hill above Chilcompton, on the road to Midsummer Norton. It is also pierced in the new coal-pit between Chilcompton and Stratton; and finally, it skirts the northern outline of the southern coal-tract along Holcombe-hill, dipping north at a considerable angle. From these localities it appears that the course of the zone of Pennant on the west and south is very tortuous; on the east it is entirely concealed by the overlying formations, and has not yet been proved in any of the collieries.

* These are the collieries on the south and south-east of Brislington; for those on the north have a southern dip, and are out of the line of bearing towards Queen's Charlton and Burnet.

In the coal-basin of Nailsea the Pennant covers an area $1\frac{1}{4}$ mile broad on Nailsea heath, and the upper seams of coal worked in that field appear to be subordinate to this rock. In the Clapton coal-field the Pennant along the line of fault abuts, as has been already stated, against the mountain limestone. The occurrence of this rock on the coast at Portishead has also been noticed.

4. The *upper coal-shale* consists principally of slaty clay, alternating with some thin beds of grit, called *greys*, a word, perhaps, of the same origin with the French *grès*. Impressions of ferns are very abundant in this shale, and some Lepidodendra occur. [See Sternberg's *Flora zur Vorwelt.*] Some of the collieries worked in the upper shale, those of Radstock for instance, are subject to the fire-damp, which is hardly known in those of the lower shale, at Bedminster or in the southern coal-tract.

The diameter of the upper shale, within the zone of Pennant, in the trough of Coal-pit heath, is rather more than 2 miles. The strata dip regularly towards the centre of the trough about 1 in 6 on an average. Three seams of coal are worked, the hard vein, the hollybush, and the great vein, containing in the aggregate from 11 to 12 feet of that mineral. (See 18th Coal-section.) They all consist of excellent slaty caking-coal, free from bad smell in burning. The hard vein, however, is sometimes stony, containing black ponderous nodules, and is of a less regular structure than the other seams. No shells have been found in the strata at Coal-pit heath. Vegetable impressions occur chiefly in the roof of the seams, immediately above the coal. The pits are free from fire-damp. The coal-measures in Coal-pit heath are traversed by several faults. One commences at Mays-hill, crosses the turnpike-road at Ox-bridge, and runs about 1 mile to the south. That near the Engine-pit at Bitterwell is supposed to be a continuation of this fault. Another occurs to the east of the Serridge engine, running westwards under the engine towards Kendleshire. A third fault is found about 1100 yards to the south of the Serridge engine, behind Wait's farm-house at Henfield, and thence runs east towards Lyde Green.

In the trough of Radford the upper coal-shale constitutes a very irregular area, whose longest diameter, from Brislington on the N.W. to Kilmersdon on the S.E., is about 12 miles, and whose shortest diameter from N.E. to S.W. is about 5 miles. Its western border follows an indented line from Brislington to Burnet, Pensford, Stanton Drew, Bishops Sutton, Clutton, Faringdon-Gurney, and Midsummer Norton. Thus far it can be traced by the range of coal-seams, which are known to be nearly contiguous to the Pennant; at the other sides of the trough its boundaries are concealed by the overlying rocks.

The first part of the western border near to Brislington presents a seam of coal, called the *rock-vein*, lying under a bed of the Pennant rock 20 feet thick; and upon this lie 3 seams of coal alternating with shale. These have been worked to the S. and S.E. of the village of Brislington, in the valley north of Queen's Charlton, and at Burnet, but are now abandoned. [See Mr. Strachey's paper above referred to in the Philosophical Transactions for 1719, and the 19th Coal-section in this Memoir]. They dip to the north nearly, in an opposite direction to the beds on the north of Brislington, proving that this part of the trough forms a very narrow tongue, in the hollow of which these seams repose.

In pursuing the western border of the shale, we next find a series of 7 coal-seams, which either are or have been worked, in the parish of Stanton Drew, and at Bishop's Sutton, Clutton, Faringdon-Gurney, and a little to the south of Midsummer Norton. (See the 20th and 21st Coal-sections.) In the parish of Stanton Drew and near Clutton these seams lie almost immediately on the Pennant rock. In some of the most northern works in the parish of Stanton Drew, as at the Bromley pits, 2 miles to the S.S.E. of Pensford, these seams dip to the east; but from this point the line of their drift appears to be very tortuous. At Sutton, and on the drift of the Sutton beds, 1 mile to the north-east of it, they dip to the south-east. They are said to have been proved dipping to the north-east, to the south of the other seams now worked at Clutton; and are certainly found 4 miles to the south-east of Sutton, at Faringdon-Gurney*, dipping as before to the south-east. Lastly, they are said to have been found dipping to the north-east $\frac{1}{4}$ of a mile to the south-west of Midsummer Norton. Some of the coal-seams, worked to the north of Holcombe, may perhaps, to judge from their position, be referred to this part of the series.

Immediately within the last series of beds on approaching the centre of the trough, we find a series of coal-seams, the most important, extensive, and best ascertained in the whole basin. The crop of these seams ranges a little to the east of the former through the parishes of Stanton Drew, Clutton, Littleton, Paulton, Midsummer Norton, and Writhlington, the dip varying from east to north-east. The strata in all the contiguous coal-works dip towards Radford as a centre; thus at Dunkerton, Priston, and Houndstreet, which lie to the north of Radford, the dip is more or less truly to the south. The highest in this series of coal-seams, the Withy-mill vein, is worked only towards the centre of the basin, at Radford, Clan Down, Timsbury and Welton; cropping out before it reaches Paulton. (See the 22d and following Coal-sections.)

* The coal at Faringdon frequently contains veins and druses of calcareous spar.

These coal-seams are kept longer in the field than they would otherwise have been, by a series of faults, the principal of which ranging from north to south through Clan Down, throws up the coal-measures on the eastern side of the fault 100 fathoms. Another ranging through the Welton works about a mile to the west of the former, throws up the measures on the same side of the fault 70 fathoms. There is another running east and west to the south of Timsbury and High Littleton, which raises the strata to the north 70 fathoms. This fault, like that of Bitton, affects the red marl and the incumbent lias. There are numerous faults of more limited extent. One of these, which traverses Paulton-hill from east to west, and raises the strata to the north 20 fathoms, affects also the overlying formations, so that the oolite on the south abuts against the lias on the north to the depth of 20 fathoms. Another fault, which affects both the coal-measures and the overlying strata, passes immediately to the north of Houndstreet. The ground here falls in three successive terraces from the hill above Houndstreet on the south to the vale of the river Chew on the north. The highest terrace is crowned with lias, the red marl appearing on its slope; the coal-measures crop out so as to form the middle terrace, on the brow of which Houndstreet is situated: on the third and lowest terrace the lias re-appears, extending eastwards from the north-east wall of Houndstreet park across the lane to Wick farm. The subsided mass of lias is for the most part horizontal, but in one place its strata are bent into a sharp arch, in the manner represented.  On the escarpment towards the river the coal-measures again appear. Here then is a fault by which the lias and the coal-measures which support it are thrown down on the north to a depth exceeding the whole thickness of the red marl.

These faults are fissures penetrating the strata in every direction, and with every degree of inclination to the horizon and to the planes of the strata which they traverse; a nearly vertical position however is by far the most common. Both the level and inclination of the strata on either side of the fault are usually altered; occasionally however they remain the same, the strata being simply fractured. The fissures are usually from a few inches to 3 feet broad, but are often of much greater dimensions. They are generally filled by a compact seam of clay, forming a natural dam or wall, impervious to water, and called the *clog*, which the miner studiously avoids to penetrate. It often happens that the edges of the strata to a certain distance from the fault, sometimes exceeding 100 feet, are so much shattered and broken, that it is impossible to work them. This shattered interval is called the *dead ground* of the fault. It will be perceived that in most of their attending circumstances these faults are analogous to the flukans of Cornwall.

The number of collieries in work formerly was probably greater than it is at present, though the total produce of the mines is certainly much greater now than at any former period. The traces of ancient workings are to be found over many whole parishes, in which not a single pit is now in use. Thus the whole line of collieries at Brislington, Queen's Charlton, and Burnet, has for many years been abandoned, as are most of those in Pensford and between Pensford and Marksbury. Most of the Kingswood pits are also deserted. The enlarged scale and spirit with which those mines are worked that are now in activity much more than compensate for the diminution in numbers.

The seams of coal are very thin* in comparison of those which are worked in the principal English coal-fields, and in most of such would be passed over as unworthy of notice. The aggregate thickness of the seams worked in any single coal-pit scarcely exceeds that of one of the ordinary seams in the principal districts; and the total of all the beds in the mining-field would be little more than double of the largest main of Staffordshire. That seams so thin should be sought for through lias and oolite, at the enormous depth of 200 fathoms, as on Clandown, must excite surprise in those acquainted only with other coal districts; and that, under these circumstances, the seams should be worked with profit, must be attributed chiefly to the highly improved machinery introduced into this district, the result of which is, that the quantity of coal delivered at the mouth of one of these pits in a single day averages at from 60 to 100 tons.

The district may be considered as able to answer largely the future demand; for, 1st, most of the ancient pits now abandoned might be drained, and worked to advantage on the present improved system; 2dly, much of the area is still untouched, as will at once be seen on referring to the collieries indicated on the Map. It will especially be seen that in the south-western angle of the basin there are no coal-pits worked to the west of Bishop's Sutton, though there is every reason to believe that the coal-measures are continued beneath the valley of Wrington between the Mendips and Broadfield Down. We have already noticed the point near Winford where the millstone grit rests against the limestone of Broadfield Down, and have stated it as probable that the lower coal-

* Where the coal-measures, however, are much deranged, as is the case with the lowest of those in the Nettlebridge district, a seam will often suddenly swell to 4 or 5 times its usual bulk, and as suddenly contract, so as nearly to vanish.

shale would be found a little to the south-east of that point in the direction of the dip. We have also assigned the grounds for believing that an unexplored coal-basin exists along the course of the Severn between Aust and Portishead-point. A trial by boring in the marshes about a mile to the west of King's Weston Down would ascertain whether coal really extends through this basin.

No coal has hitherto been found to the south of the Mendip range; but since the mountain limestone dips beneath the marshes in that direction, and re-emerges in Cannington Park on the north of the Quantoc range, it seems probable that there exists an intermediate basin beneath the red marl, which forms the uppermost substratum in this alluvial tract.

SECTIONS OF COAL-MEASURES.

Section 1.

In lower coal-shale, at Pucklechurch, on the eastern side of the northern coal-tract.

Dip N.N.W. 1 in 3.

Descending order.	Fath.	Ft.	In.
Lias	?		
Red marl	?		
Duns and stone	?		
1. *Hard seam**	0	2	0
Duns and stone	35	0	0
2. *Top seam*	0	2	0
Duns and stone	6	0	0
3. *Hollybush seam*	0	3	0
Duns and stone	6	0	0
4. *Great seam*	0	3	6

* *Vein* is the technical term used by the miners throughout the Bristol Coal-basin to designate a bed of coal; but since this term is already appropriated in Geology to the fissures filled with solid stony matter, that intersect the strata, we have substituted for it the word *seam*. *Course* is the term used in the southern coal-tract, when the beds are nearly vertical. *Delf* is the term in the Forest of Dean. In this and the following sections the names of the seams are printed in italics.

Section 2.

In lower coal-shale, on the northern side of Kingswood, between Mangotsfield and Fishponds.

Dip northerly.

Descending order.	Fath.	Ft.	In.	
Hard rock	65	0	0	Beds worked in Mr. Hillhouse's pits, and in those at* Staple-hill and Ridgeway. Dip usually less than 1 in 2. At the Cockpit in Stapleton, the beds are nearly vertical.
1. *Rattlebones seam;* hard coal divided by a parting	0	2	0	
Hard black rock	85	0	0	
2. *Stinking seam*	0	1	6	
Duns or cliff	5	0	0	
Hard rock	78	0	0	
3. *Cock seam* { tender coal, parting of shale, smith's coal } { sometimes 3 feet. }	0	2	0	
Hard rock (according to Mr. Brain 20 fath.)	7	0	0	
4. *Chick seam*	0	1	6	
Duns and some rock	30	0	0	
5. *Hen seam*	0	2	6	
Interval	90	0	0	
6. *Golden Cock seam* [tender small coal]	0	1	6	Shepherd's or Bragg's works. Dip from 1 in 2 to 2 in 3.
Interval	100	0	0	
7. *Britton's seam* [smiths' coal]	0	1	2	
Interval	50	0	0	
8. *Stubb's seam* [hard coal]	0	3	0	
Interval	13	0	0	
9. *Shelly seam* [Brash coal]	0	3	0	
Interval	9	0	0	
10. *Hard seam* [sometimes 2 feet]	0	1	7	
Interval, Pennant and Duns	60	0	0	Soundwell pits dip from 1 in 2 to 2 in 3. To the south of these pits the strata undulate.
11. *Five-coal seam*	0	4	0	
Pennant and Duns, containing occasionally a thin coal seam	10	0	0	
12. *Great seam*	0	4	0	
Pennant and Duns	10	0	0	
13. *Gillers-inn seam*	0	1	6	
Pennant	20	0	0	
14. *Two-foot seam*	0	1	10	
Duns	8	0	0	
15. *Slate seam*	0	1	8	
Duns	4	0	0	
16. *Pig's-cheek seam*	0	1	0	
Pennant and Duns	4	0	0	
17. *Trumpet seam*	0	0	10	
Argillaceous grit-stone	10	0	0	
18. *Stoney seam*	0	1	4	
Pennant and Duns	30	0	0	
19. *Smiths'-coal seam*, from 1 foot to	0	4	0	
Pennant, very hard	30	0	0	

At this depth a horizontal gallery was driven southwards to the distance of 15 fathoms, without cutting any other coal-seam; but it penetrated at its southern end a copious spring of strong brine.

* In Mr. Hillhouse's estate, close to the road, between Mangotsfield and Fishponds, two faults traverse the works from north to south, of which the western throws down the beds on the eastern side from 20 to 30 fathoms, the eastern 40 fathoms.

Section 3.

In lower coal-shale, on the southern side of Kingswood, and on the north bank of the Avon, between Bitton and Bristol, at Golden Valley, Haul Lane, Custom-hill, Hanham, Crew's hole, and Pyle marsh. The whole of this series has been driven through by a great cross level in Mr. Whittack's workings between the new level colliery and the river Avon. The dip is from S. to S.W., 1 in 2. The following vertical section is obtained by halving the horizontal intervals observed in the cross drift.

	Descending order.	Fath.	Ft.	In.
1 and 2.	*Two seams un-named.*			
3.	*A thin seam*	0	0	6
	Interval	75	0	0
4.	*Fig seam*	0	0	8
	Interval	8	0	0
5.	*Francombe seam*, from 6 inches to	0	2	0
	Interval	6	0	0
6.	*Mill-grit seam*, sometimes parted into 2 seams, from 1 foot to	0	3	0
	Duns	6	0	0
7.	*Rag seam*, from 0 to	0	5	0
	Duns	12	3	0
8.	*Devil's seam*, from 9 in. to	0	3	0
	Interval	3	3	0
9.	*Buff seam*, from 1 foot to	1	0	0
	Interval	10	0	0
10.	*Parrot's* or *Smith's seam*, from 1 foot to	0	3	0
	Interval	1	3	0
11.	*Little seam*	0	0	8
	Interval	4	3	0
12.	*Brimstone seam*	0	0	8
	Interval	25	0	0
13.	*Muxton seam*, very variable in thickness	?	?	?
	Interval	37	3	0
14.	*Scragg seam*	0	1	6
	Interval	22	0	0
15.	*Great seam*	0	1	6

Beneath is a little seam, called Plox, of variable thickness.

Section 4.

Seams in lower coal-shale, worked at Whitehall, and also at the distance of about a mile to the west-south-west, near the foot of Lawrence-hill, behind the Packhorse, on the north-eastern suburb of Bristol. The seams agree with the lowest at Hanham; but it is so long since they were worked, that it has been found impossible to obtain more than an imperfect account of them.

Dip southerly.

	Descending order.	Fath.	Ft.	In.
	Red marl	?	?	?
	Duns	?	?	?
1.	*Dolly seam* [Brimstone seam at Hanham?]	0	1	2
	Duns, principally, about	5	0	0

(Section 4. continued.)	Fath.	Ft.	In.
2. *Faulty seam* [Muxton seam at Hanham ?] .	0	3	0
Duns, principally, about . . .	5	0	0
3. *Scragg seam* [position and thickness of this seam not exactly remembered by the miners]		?	?
Duns, principally about . . .	5	0	0
4. *Stony seam* [Great seam at Hanham ?] .	0	3	0
Duns, principally, about . . .	5	0	0
5. *Plox seam*, variable, sometimes . .	1	1	0

Section 5.

Immediately below the Whitehall seams, are those worked at Easton. The strata at Easton range in an east-north-easterly direction, by the Duncombe liberty, towards the Lodge collieries, and in a south-westerly direction, by the eastern suburbs of Bristol, directly towards the collieries of Bedminster. The Easton seams must therefore pass beneath the southern part of Bristol.

Dip south-easterly, 1 in 3 towards the crop, but less in the deep.

	Descending order.	Fath.	Ft.	In.
Southern pit, 1 furlong north of Upper Easton	Newer red sandstone . . .	12	0	0
	Duns	18	0	0
	1. *Queen's-bower coal* (not worked) . .		?	?
	Duns	18	0	0
	2. *Polecat coal*	0	1	6
Middle pit	Duns	?	?	?
	3. *Dog's-hill coal* . . .	?	?	?
Northern pit	Duns, from 4 to . . .	20	0	0
	4. *Primrose coal*, in 2 seams with a parting .	0	2	0
	Duns	9	0	0
	5. *Little seam*	0	1	6
	Hard rock	3	0	0
	Duns	4	0	0
	6. *Toad seam*, { good coal 2 ft. 6 in. / shaly coal 6 } . . .	0	3	0

Below these seams another was worked, in a pit 100 yards east of the Armoury, in the eastern suburb of Bristol. Two or three other seams have been worked in the Duncombe collieries; but we have not been able to obtain any information concerning them.

Section 6.

In lower coal-shale, at Bedminster, in the western coal tract.

Dip S.S.E. 1 in 3.

Descending order.	Fath.	Ft.	In.
Alluvial blue clay, with trunks of trees . .	4	0	0
Red ground	6	0	0
Cliff or duns	20	0	0
Greys, a compact grey gritstone, with argillaceous mixture	3	0	0
1. *Hard seam*, not worked . . .	0	1	0
Under-earth, a friable grit . . .	6	0	0
2. *Top seam*	0	2	6
Under-earth	1	0	0
3. *Little seam*, not worked . . .	0	1	2

(Section 6. continued.)	Fath.	Ft.	In.
Cliff and stone	10	0	0
4. *Coal*, not worked	0	1	0
Cliff and stone	9	0	0
5. *Great seam*	0	3	4
Cliff and stone	14	0	0
6. *Thin seam*, occasionally worked	0	1	8

The top seam lies 40 fathoms deep in the northernmost pit, called Mash pit, and 116 fathoms deep in the southernmost pit, about 1000 yards distant from the former. All the seams consist of caking coal. Many impressions of lepido-dendra and syringo-dendra occur above the great seam. The greatest fault throws up the beds 19 fathoms on its north side.

Section 7.

In lower coal-shale, at Ashton, in the western coal-tract. Mr. Gore's coal-work. From Mr. Catcott's MSS.

Dip northerly.

Descending order.	Fath.	Ft.	In.
Vegetable mould	0	1	0
Stiff light-coloured clay	0	0	6
Red gritty clay	4	3	0
Duns, with vegetable impressions	3	0	0
Hard grey stone	0	4	0
Duns	0	2	0
1. *Flaky bad coal*	0	1	0
Flaky, black substance (shale with coal intermixed)	0	1	6
2. *Coal*	0	3	6

A fault runs north-west and south-east, near to which the beds are vertical. In another pit 20 yards to the south of the former, the dip is to the south. Another fault, perpendicular to the former one, runs probably between the two works.

Section 8.

In lower coal-shale, at Newton St. Leo: as communicated by Richard Harver, underground bailiff. The seams are said to be the same as those worked in the Golden valley.

Dip N.W. 1 in 3.

Descending order.	Fath.	Ft.	In.
Grey rock	35	0	0
1. *Coal seam*	0	2	0
Cliff	16	0	0
2. *Coal seam*	0	0	10
Cliff	10	0	0
3. *Coal seam*	0	3	0
Cliff	16	0	0
Ring-stones?	0	0	6
4. *Coal seam*	0	3	0
Cliff and duns	4	0	0
5. *Coal seam*	0	2	0

Section 9.

In Pennant rock, and lower coal-shale, at Nailsea. See Phil. Mag. 1811.

Descending order.	Fath.	Ft.	In.	
Rubble	1	0	0	worked in the pits nearest the church. Dip S. 2 in 9.
1. *Withey seam*	0	4	0	
Rock	a few fathoms			
2. *Seam* mentioned in the Phil. Mag. as above No. 3.	0	2	0	worked in White's collieries, immediately west of the Glass-house. Dip from S. to S.W., 2 in 9.
3. *King's-hill seam*	0	1	4	
Pennant	a few fathoms			
4. *Rock seam* (not mentioned in Phil. Mag.)	0	1	4	
Duns	3	0	0	
Rock	3	0	0	
Duns	3	0	0	
5. *White's or Main coal.* There is no Pennant below this seam	0	3	6	
Cliff	a few fathoms			
6. *Dungy seam*	0	1	8	
Cliff	a few fathoms			
7. *Little seam* (not mentioned in Phil. Mag.)	0	1	4	
Cliff	a few fathoms			
8. *Violet seam*	0	0	10	

An interval follows, which has not been thoroughly examined. The new pit at Backwell, which is said to be sunk in this interval, exhibits, beneath overlying red marl, the following beds :

	Fath.	Ft.	In.	
Rubbly rock	3	0	0	New pit at Backwell. Dip N.N.W. 1 in 4.
Duns	10	0	0	
9. *Little rock seam*, good coal	0	1	8	
Duns, not sunk through	4	0	0	
Duns and stone	10	0	0	Old pits at Backwell, called Teague's colliery at Backwell in the Phil. Mag. Dip N.N.W. 1 in 4.
10. *Smith's seam*, variable in thickness	0	5	0	
Duns &c.	13	0	0	
11. *Dog coal*, a good fire coal. It has a thin argillaceous parting, and swells into large irregular masses	0	3	0	
Duns	1	3	0	
12. *Spider delf coal*, good coal	0	2	0	
Duns	10	0	0	
13. *Crow seam*, good coal	0	3	0	
Below this two other thin seams have been proved, viz.				
14. *Milway seam*				
15. *Rock seam*				

The faults in the Nailsea coal-field are few and inconsiderable.

List of coal seams in the southern coal-tract, and in the lower coal-shale between Emborrow and Mells, on the authority of Gregory Stock, mining agent at Ashwick.

Descending Order, beginning with the most northerly.

	Name of the Seam.	Thickness. Feet.	In.	Where worked.	Variation between this and other accounts.
1	The Owls nest seam			Lookham, ¼ mile N. of Holcombe church	
2	The Lookham seam				
3	Gent's course				
4	The north course				
5	The globe				
6	Small coal	3	0	Rock, the uppermost seam in Stratton	
7	Two seams, with parting of fire-clay	2	0	Rock	
8	Shell seam, not worked	0	7	Rock, Holcombe	
9	Warkey course	5	0	Rock, Stratton	
10	Dead course, bad coal	3	0	Rock	
11	Garden course	3	6	Rock, Stratton	Other small seams occur on Stratton - common interspersed among those mentioned. Their names are the Snotty nose, Hen's nest, Two coal, Tobacco, Granfer - Hamlyn, Gout, and Crock courses.
12	Two shales	1	0	Rock	
13	Strap	2	6	Rock, Stratton	
14	Great course	4	0	Barlake, Rock, Newbury, Chilcompton	
15	Firestone seam	3	0	Barlake	
16	Little or dead course	1	6	Bentor and Barlake	
17	Stone coal	1	0	Bentor	Stone coal, South course, or Dick Daniel, Dungy drift, Foot coal of Dungy drift, Hard coal drift.
18	Dungy drift	2	0	Bentor	
19	Hard coal drift	3	0	South of Rockpit, Bentor	
20	Perkins course	2	0	South of Rockpit	
21	Foot coal	2	0	Stratton common	

Name of the Seam.	Thickness. Feet.	In.	Where worked.	Variation between this and other accounts.
22 Branch	4	0	Ashwick, Stratton common. This is the uppermost seam in Ashwick on the S. of the Nettlebridge river	The Beggar
23 Golden candlestick	2	6	Ibid.	
24 North sheets. . .	4	0	Ibid.	North sheets
25 Cat, hard coal burning to red ashes .	1	0	Ibid.	Little Dickshell Pig's tail
26 South sheets . . .	3	0	Ibid.	Ribband Flat course South sheets
27 Ribband	1	2	Ibid.	
28 Standing coal . .	4	0	Ashwick	Several seams are mentioned as occurring between the Ribband and the Standing coal, viz. 1 The Rosemary branch 2 The Wilmot 3 The Mouse 4 The Cat of Wilddrift 5 The north flap of Wilddrift 6 The Wilddrift 7 A seam whose name is forgotten 8 A thin nameless seam 9 The Cat of Butterakes 10 The Butterakes 11 The Blessing 12 The Cat
29 Blue pot, irregular in thickness . . .	2	0	Ashwick	
30 Shale of Fern rag, not worked . . .	1	0	Ashwick	
31 Fern rag	2	0	Ashwick, Edford, Moorwood	
32 Stone rag, hard and good coal . . .	2	6	Ibid.	
33 Callows, the thickest in the series, often swelling to 10, 12, or even 20 feet	6	0	West of Ashwick river, Edford, Moorwood, Goodeaves	
Iron-stone occurs in this interval.				
34 Wing, not much worked	2	0	Ashwick and Edford	
35 Perrink or Blackstone	3	6	Ashwick, Moorwood, Edford, Goodeaves	North Perrink South Perrink
36 White axen, [*i. e.* ashes]	3	0	Moorwood	White Axen Red Axen Akerman's Dream
37 Firestone seam . .	2	6	West of Moorwood near the mill, Akingtons in Ashwick, Selways	

Note. The 8 following Sections all belong to pits worked in the lower coal-shale, in the southern coal-tract; the numbers prefixed to the coal seams refer to the numbers in the preceding list.—The order is descending, beginning with the northernmost seams.

SECTION 10.

Chilcompton new pit.

Dip nearly E., 5 in 12.

		Fath.	Ft.	In.
	Overlying dolomitic conglomerate or millstone	23	0	0
	Firestone or Pennant	13	3	0
?	*Coal*	0	0	5
	Benching, a kind of clay	0	0	5
	Pan or coat of mail, a kind of clay	0	3	0
	Cliff	3	0	0
?	*Shaly coal*	0	0	3
	Pan	0	2	0
	Imperfect, shaly coal	0	0	6
	Pan	2	3	0
	Firestone	12	3	0
?	*Imperfect coal*	0	3	0
	Firestone	3	0	0
	Cliff	4	3	0
	Pan	1	0	0
	Grey firestone	3	0	0
	Strong cliff	5	0	0
6.	*Small-coal seam*	0	3	0
	Cliff	2	0	0
7.	*Two-coal seam*	0	2	0
	Greys	12	3	0
9.	*Warkey course*, half coal, half shale	1	0	0

The uppermost measures in this Section appear to belong to the Pennant.

SECTION 11.

At Holcombe.

Dip S., 7 in 12, and very regular.

		Fath.	Ft.	In.
6.	*Small-coal seam*	0	3	0
	Rock and cliff	25	0	0
9.	*Warkey course*, divided into two seams	1	0	0
	Rock and cliff	50	0	0
11.	*Garden course*	0	3	0

The beds to the south of these are the same as those in section 12.

SECTION 12.

At Rock, near Pitcot.

Dip. N.E., 1 in 2.

The vertical dimensions of these beds are inferred from their horizontal thickness observed in a horizontal drift.

	Fath.	Ft.	In.			
Overlying beds of dolomitic conglomerate or millstone	———			16	0	0
Firestone	20	0	0			

	Fath.	Ft.	In.			
Brought forward				16	0	0
(Section 12 continued.)						
Cliff	2	0	0			
6. *Small-coal seam*	0	3	0			
Cliff	3	3	0			
7. *Two-coal seam*	0	2	0			
Cliff	5	0	0			
8. *Shell seam*, bad coal	0	5	0			
Cliff	9	3	0			
9. *Warkey course*, 3 seams, with shale partings containing $2\frac{1}{2}$ feet of coal	1	0	0			
Firestone	7	3	0			
10. *Dead seam*	0	1	0			
Firestone	7	3	0			
11. *Garden course*	2	2	0			
Cliff, containing 2 thin seams of coal	12	3	0			
13. *Strap*	0	1	6			
Cliff	5	0	0			
Firestone	20	0	0			
Cliff	0	3	0			
14. *Great course*	0	4	0			
Firestone	3	3	0			
Total of coal-measures				102	3	6
				118	3	6

SECTION 13.

At Barlake, between Pitcot and Newbury.

Strata nearly vertical, or dipping S. at a very high angle.

	Fath.	Ft.	In.
14. *Great course*	0	4	0
Cliff and firestone	7	0	0
Firestone and strap	1	3	0
15. *Firestone seam*	0	3	0
Firestone and cliff	8	0	0
16. *Little course*	0	2	0

SECTION 14.

At Newbury.

Dip S., 5 in 12.

	Fath.	Ft.	In.
14. *Great course*	0	4	0
Shale	6	0	0
Firestone	20	0	0
15. *Firestone seam*	0	2	0
Cliff	5	0	0
Firestone	25	0	0
16. *Little course*, not worked, being two thin seams, together 6 inches thick, parted by shale	1	0	0
Shale, and a little rock	30	0	0
17. *Stone coal*, not worked	0	1	0
Cliff	10	0	0
Firestone	10	0	0

These seams are also worked at Lypcote, and Cherry garden.

SECTION 15.

List of seams worked at Pitcot.

Towards the middle of the work the beds are vertical; towards the west they dip north; towards the east, being thrown over, they dip south.

		Ft.	In.
	Great course	5	0
18.	Dungy drift	2	6
19.	Hard coal drift	3	0
20.	Perkins course	5	0
21.	Foot course	1	0
	Great seam	5	0

SECTION 16.

Seams of coal worked at Ashwick, from the Bailiff of Moorwood.

Dip varying from N. to N.E. at 45°, and diminishing as the beds recede from the Mendip chain.

	Fath.	Ft.	In.
Overlying beds of red marl, and dolomitic conglomerate or millstone	15	0	0

			Ft.	In.
Seams of coal, viz.	29.	Blue pot	1	6
	30.	Shale of fern rag	1	0
	31.	Fern rag	2	6
	32.	Stone rag	3	0
	33.	Callows	4	0
	35.	Perrink	3	0
	36.	White Axen	2	6
	37.	Firestone seam	2	0

These seams are worked at Edford and Moorwood, and also at Emborrow mere; the Perrink and Callows on the south of the mere, the Stone rag and Fern rag on the north of it. At Emborrow the dip is easterly.

SECTION 17.

At Goodeaves pit, from the Bailiff, Mr. Jefferies.

The dip in general is southerly, but sometimes it becomes northerly. The beds are sometimes vertical, but never continue so above 10 fathoms. The line of bearing is N.E. and S.W., as it is at Newbury. Faults are frequent which throw up the measures on the northern side.

	Fath.	Ft.	In.
Under callows	1	4	0
Cliff	6	0	0
Strap coal, from 1 foot to	0	3	0
Shaly cliff, from 8 inches to	5	0	0
33.**Callows, or main coal*, leaving a white ash, sometimes 2 fath.	1	0	0

* The callows has a mealy joint in the middle, 5 or 6 inches thick, which is covered with marl, and burns to a white ash. The mealy joint is divided by a parting as thin as paper, which occurs at Vobster, Bilborough, Old Goodeaves, New Ringing pit, Coal Barton, Edford Mash, and Melcombe Wood.

(Section 17 continued.)

		Fath.	Ft.	In.
	Soft cliff, called the Ridge-wash	1	0	0
34.	*Shelly coal*	0	1	8
	Cliff and greys, not much stone	20	0	0
35.	*Perrink*	0	3	6
	Cliff and a little duns	18	0	0
37.	*Red-axen seam*	0	1	0
	Dunstone and cliff	22	0	0

All the Sections that follow belong to the upper coal-shale.

Section 18.

Of the Engine pit, at Bitterwell, the deepest sunk in the trough of Coal-pit heath.

Dip E., about 1 in 9.

			Fath.	Ft.	In.	Fath.	Ft.	In.
Overlying beds, viz.		Clay	1	0	0			
		Red marl	13	0	0			
		Red-stone grit	1	0	0			
		Red marl	30	0	0			
		Total of overlying beds				45	0	0
Coal measures, viz.		Rock	1	0	0			
	1.	*Coal*	0	0	4			
		Lower earth, a black heavy stone found beneath all the seams	1	0	0			
		Duns	5	0	0			
		Rag, or thin seams of coal, alternating with black, soft, slaty duns	0	5	0			
	2.	*Rag coal*	0	1	0			
		Lower earth	1	0	0			
		Soft duns	0	2	0			
		Hard-seam stone	2	0	0			
		Duns	1	4	0			
	3.	*Hard seam*	0	2	6			
		Lower earth	1	3	0			
		Duns	1	0	0			
		Stinker stone	2	3	0			
		Black slaty duns	2	0	0			
	4.	*Stinker coal*	0	1	0			
		Lower earth	1	3	0			
		Duns	0	3	0			
		Hollybush stone	2	0	0			
		Duns	1	4	0			
	5.	*Hollybush coal*	0	2	6			
		Lower earth	1	3	0			
		Hard duns	5	3	0			
		Great-seam stone	2	0	0			
		Duns	2	0	0			
		Great seam: Top coal 2 ft. 0 in.; Benching 6; Middle coal 2 0; Bottom coal 2 0	1	0	6			
		Total of coal measures				38	4	10
						83	4	10

Section 19.

Of pits formerly worked to the south of Brislington, and at Queen's Charlton, and Burnet. From Strachey's Memoir in the Philosophical Transactions for 1719.

Dip nearly N., 1 in 3.

		Fath.	Ft.	In.
	Overlying red earth from 10 fath. to	30	0	0
Coal measures	1. *Uppermost seam* from 3 feet to (but not so thick at Charlton and Burnet.)	1	0	0
	Cliff	6	0	0
	2. *Pot seam*, hard coal	0	1	6
	Cliff	7	0	0
	3. *Trench seam*, solid, from 2 feet 6 in. to	0	3	0
	Pennant rock	3	2	0
	Cliff	3	4	0
	4. *Rock seam*, worked in pits 200 yards to the south of those in which the former seams were worked.			

Section 20.

Of pits formerly worked at Bishop's-Sutton, near Stowey, in the parish of Chew-Magna; about 1 mile N.E. of Bishop's-Sutton, in the parish of Stanton-Drew; and at Faringdon-Gurney, 4 miles S.E. of Bishop's-Sutton. From Strachey's Memoir in the Philosophical Transactions for 1719, verified by our own inquiries.

At Bishop's-Sutton, Stanton-Drew, and Faringdon-Gurney, dip S.E., nearly 1 in 3.

In the northernmost pits in the parish of Stanton-Drew, dip nearly E.

		Fath.	Ft.	In.			
Lias formation.	Stony arable, mixed with spongy yellow earth or clay	0	2	0			
	Lias limestone	1	4	0			
	Yellow loam	1	0	0			
	Blue clay, inclining to marl	0	3	0			
	Whitish loam	0	3	0			
	Deep-blue marl, soft, fat, and soapy	0	2	0			
	Iron pyrites	0	0	6			
	Deep-blue marl	0	3	6			
					5	0	0
Newer red sandstone.	Red earth, becoming a malm at the surface	10	0	0			
	Reddish firestone, from 4 to	5	0	0			
	Greyish millstone [dolomitic conglomerate] 3 feet at Sutton; at Faringdon	1	4	0			
					16	4	0

These coal-pits are not sunk through the lias, which is found on the hills, but through the red marl in the valleys. There is but little red marl on the surface in the parish of Stanton-Drew, where you arrive almost immediately at the coal measures. At Sutton and Faringdon, the red marl varies in thickness from 4 or 5, to 12 or 14 fathoms.

(Section 20 continued.)

		Fath.	Ft.	In.			
Coal measures.	Coal-clives	6	0	0			
	1. *Stinking seam*, hard and sulphureous .	0	2	0			
	Cliff and duns, from 5½ to . .	7	0	0			
	2. *Cat-head seam* (from lumps of stone called cat-heads) . . .	0	2	6			
	Cliff and duns, from 5½ to . .	7	0	0			
	3. *Three-coal seam* { coal, stone, from 1 to 2 feet, coal, stone parting, coal }	0	3	0			
	Hard cliff, subject to water, and containing cockles and ferns, from 8 to	10	0	0			
	4. *Peaw* (i. e. *Peacock*) *seam* (iridescent coal)	0	2	0			
	Cliff	6	0	0			
	5. *Smith's coal* . . .	0	3	0			
	Cliff	6	0	0			
	6. *Shelly* (*shaly*) *seam* . . .	0	2	6			
	Cliff	6	0	0			
	7. *Ten-inch seam* . . .	0	0	10			
					50	3	10

At Faringdon-Gurney in 1820 the pits were about 100 fathoms deep.

Section 21.

Of Mr. Fowler's pits, in Coal-pit lane, at Bromley, 2 miles S.S.E. of Ponsford. They are not now worked. The seams agree nearly with those of Bishop's-Sutton.

Dip due E., 1 in 3.

	Fath.	Ft.	In.
Duns and paving-stone . .	20	0	0
2. *Great seam* (cat-head) . .	0	2	4
Duns, &c. . . .	7	0	0
3. *Three-coal seam* . .	0	1	6
Duns, &c. . . .	7	0	0
4. *Peaw* seam . . .	0	1	4
Duns, &c. . . .	7	0	0
5. *Smith's coal* . . .	0	2	0
Duns, &c. . . .	4	0	0
6. *Shelly seam?* . . .	0	1	10
Duns, &c. . . .	7	0	0
7. *Coal* . . .	0	1	0
Duns, &c. . . .	3	0	0
8. *Coal* . . .	0	1	0
	56	5	0

Numbers 7 and 8 are now worked in two pits, belonging to Messrs. Anstey and Dowling, a little to the west of Mr. Fowler's. About ¾ of a mile further to the west a trial is now being made for coal in fissile Pennant, by Mr. Burdett. To the north of Coal-pit lane by Stanton-wick are numerous old pits. One pit is now working about a mile to the north, belonging to Mr. Rydon. The seams are said to be those of Clutton or Radford.

SECTION 22.

On Clan Down.

		Fath.	Ft.	In.	Fath.	Ft.	In.
Lias.	Blue clay	1	3	0			
	Gritty lias	0	4	0			
	Blue clay	0	1	6			
	Corn grit, 3 beds	0	1	6			
	White lias	2	0	0			
	Knotty claystone	1	0	0			
	Grey or blue marlstone	0	5	0			
	Darker marlstone	0	1	0			
	Black marl, good manure	2	0	0			
					8	4	0
Newer red sandstone.	Green marlstone, full of knotty concretions	2	0	0			
	Soft red rock-marl	4	0	0			
	Hard ditto, blasted in sinking	14	0	0			
	White-stone	0	0	4			
	Hard red rock-marl	15	0	0			
	Sandy millstone (dolomitic conglomerate)	2	0	0			
					37	0	4
Coal-measures.	Grit and shale, with impressions of plants	68	0	0			
	1. *Withy mill seam*	0	1	0			
	Grit and shale	51	0	0			
	[The coal-measures here become shattered in the shaft, but become solid in the horizontal adit.]						
	2. *Top coal, or great seam*	0	2	0			
	Cliff and greys	11	0	0			
	3. *Little seam*	0	1	8			
	Cliff and greys, containing the 3-coal seam	7	0	0			
	4. *Middle seam*	0	2	0			
	Cliff and greys	14	0	0			
	5. *Stiving seam*	0	2	0			
	Cliff and greys	4	0	0			
	6. *Little seam*	0	1	4			
					156	4	0
					202	2	4

Beds at Radford, according to Mr. Kelson

		Fath.	Ft.	In.
Newer red sandstone.	Red ground, from 10 to	12	0	0
	Millstone	1	0	0
		13	0	0
Coal-measures in a trough, cropping out all round.	Clives, not hard	60	0	0
	1. *Withy mill seam*	0	1	0
	The lower coal-measures as on Clandown, &c.			

Beds above the Great seam, according to Mr. Hill.

	Fath.	Ft.	In.
Cliff and shale, thickest on Clandown	70	0	0
1. *Withy-mill seam*	0	0	10
Cliff, greys and rubble	40	0	0
* 1. *Ore seam*, sulphureous, not worked	0	0	6
Clives	5	0	0
* * 1. *Shale coal*	0	0	5
Greys and cliff intermixed	15	0	0
Shale of great seam (imperfect coal)	2	0	0
Broken, rubbly clives	7	0	0
Plastic clay	0	0	5
Great seam greys	4	0	0
Cliff	4	0	0
2. *Great seam*	0	2	0
	147	4	2

		SECTION 23. New Welton Pit, Midsummer Norton. Dip N.E., 1 in 3. Fath. Ft. In.		SECTION 24. Paulton Lower Pit. Dip E., 1 in 4½. Fath. Ft. In.		SECTION 25. Pit on the hill East of Paulton, worked between 1790 and 1800 by Mr. Simon Hill. Dip E.N.E., 1 in 4.	Fath. Ft. In.	
Overlying beds.	Inferior oolite .	.	.	.	.	. . . .		3 0 0
						Blue marl . .	20 0 0	
						Grey and blue lias, making strongest lime	1 0 0	
						Sun-bed, blue, burns to good white lime [known at Paulton, Timsbury, Dunkerton and Clandown]	0 1 6	
						White lias . .	2 0 0	
						Blue marl . .	1 0 0	
						Crumples, a knotty claystone .	0 3 0	
						Black marl, excellent manure .	1 0 0	
	Lias . . .			(at grove work)	2 3 0	Total of lias .		25 4 6
	Red ground . .	19 0 0		18 0 0		. . . .	22 0 0	
	Millstone . .	1 0 0		0 0 0		. . . .	1 0 0	
	Newer red sandstone .		20 0 0		18 0 0	. . . .		23 0 0
	Greys and cliff . .	40 0 0		28 0 0	(red cliff)	. . (Cliff) . .	14 0 0	
	2. *Great seam* of Clandown .	0 2 0		0 2 1		. . . .	0 2 4	
	Greys and cliff (greys always uppermost) .	6 3 0		6 0 0		. . (variable) .	6 0 0	
	3. *Little seam* . .	0 1 6		0 1 6		. . . .	0 1 8	
	Greys and cliff .	} 10 0 0		4 0 0		. . . .	4 0 0	
	3.* *Three-coal seam* .			0 1 10	(not worked)	. . coal and dung from 1 ft. to .	0 3 0	
	Greys and cliff .			10 0 0		. . . .	7 0 0	
	4. *Middle seam* . .	0 1 8	(very bad)	0 1 8	(not worked)	. . (variable) .	0 1 8	
	[worked at Radstock, Welton, and Camerton—not worked at Paulton, Timsbury, and Clutton.]							
	Greys and cliff . .	16 3 0		14 0 0		. . . .	12 0 0	
	5. *Stiving seam* . .	0 2 6		0 2 6		. . . .	0 2 4	
	Greys and cliff . .	6 3 0		6 0 0		. . . .	7 0 0	
	6. *Little seam* . .	0 1 4		0 1 4		. . . .	0 1 6	
	Greys and cliff . .	.	.	.	.	. . . .	6 0 0	
	7. *Bull seam*, not worked .	.	.	.	.	. . . .	0 0 10	
	Greys and cliff . .	.	.	.	.	. . . .	2 0 0	
	8. *Peaw seam* (iridescent) .	.	.	.	.	. . . .	0 0 10	
Coal measures	. . . .		81 0 0		69 4 11	. . . . .		60 2 2
	Total depth of pit .	.	101 0 0		90 1 11	. . . . .		112 0 8

Below the Peaw seam, cliff and greys were sunk through to the depth of 80 fathoms at Mearns in High Littleton in the year 1815; but no coal was found.

Section 26.

The following seams are mentioned in Mr. Strachey's Memoir in the Philos. Trans. for 1719, as being worked in the parish of Stanton-Drew, a little to the east of those mentioned in Section 20, and at Clutton, on the same drift, to the south by east.

Dip E. by N., 1 in 3.

At Clutton there are from 10 to 14 fathoms of red earth ; at Stanton-Drew the coal-measures rise to the surface.

		Fath.	Ft.	In.
	Greys and cliff	0	0	0
1.	*Small lime coal*	0	3	0
	Cliff	3	0	0
2.	*Coal* fit for culinary purposes	0	2	6
	Cliff	3	0	0
3.	*Good hard coal*	2	0	10

Chapter III.—ON THE COAL-BASIN OF THE FOREST OF DEAN.

Having given in the introductory chapter a general account of this coal-basin, we shall now describe more fully its principal inclined formations, and the characters and more remarkable local phenomena which here distinguish them.

For much of the information contained in this chapter, and for the accurate sections [see Plate XXXII. fig. 5. and the section at page 288.] appended to it, we are indebted to the author of those sections, that able metallurgist and engineer, Mr. David Mushet of Coleford *. The most important natural display of the structure represented in the sections is afforded along a line running east and west from May-hill, through Longhope and Mitchel Dean, to the borders of the Forest. We have there a regular series of the beds from grey-wacké to the coal-measures, all dipping conformably to one another, and westwards at a high angle.

1. Grey-wacké.

The formation, to which we here apply the term *grey-wacké,* consists of

* These sections were presented by their author to the Geological Society, in the years 1812 and 1815. We are happy to learn, that he has it in contemplation to publish a volume on the Geology, Mines, Metallurgy, and mining customs of the Forest of Dean.

highly inclined beds of slaty micaceous sandstone, alternating with and passing into, on the one hand, a coarse breccia having grains as large as peas; on the other, a soft argillaceous slate. It contains occasionally subordinate beds of granular glassy quartz-rock, but its general aspect is that of a coarse grey sandstone, resembling one of the siliceous coal-grits.

These varieties of grey-wacké occur on the north-eastern border of the Forest, near the southern extremity of the chain of transition limestone, which we have before described as extending from Stoke Edith, near Hereford, to Flaxley on the Severn. They are here connected with the transition limestone, and occupy a very limited tract, constituting the central and most elevated portion of an insulated hill, called May-hill, which rises 965 feet above the sea, and extends in length from N. to S. about $1\frac{1}{2}$ mile, and about $\frac{3}{4}$ of a mile in breadth. The southern extremity of this hill is traversed by a defile through which winds the road from Gloucester to Ross. The abruptness of this pass is sufficient to give it a wild and mountainous character, and affords the best opportunity of examining the varieties of the rock.

2. Transition limestone.

The *lower beds* of this formation, which lie between the granular strata of grey-wacké just described, and those of the rock to which the term *transition limestone* is strictly applicable, consist of fine-grained, tender, extremely argillaceous slate, loose in texture, and assuming imperfectly the character of grey-wacké slate. This shale is commonly known in the district by the name of *water-stone*, in consequence of the wet soil that is found wherever it appears at the surface. In its most compact form it scarcely differs from common grey-wacké slate, between the water-stone and which it is as difficult to draw a line of separation, as it is between the grey-wacké slate and primitive clay-slate. The water-stone is never sufficiently strong to be used as roofing slate, and instead of being tinted with blue or purple like the older and harder slates, it is commonly of a muddy green colour, approaching to brown. Calcareous matter is interspersed in it but sparingly, and it alternates occasionally with subordinate beds of fine-grained sandy flag-stone and porous sandy slate.

The occurrence of this water-stone is by no means limited to the ridge of hills extending from May-hill to the neighbourhood of Hereford; it forms also a considerable part of that range which stretches on the west of the Malvern Hills from Ledbury to Abberley, and which has been described by Mr. Horner in the 1st volume of the Geological Transactions. In Shropshire, it occupies the valley between the long and parallel ranges of Wenlock-edge and Caer-Caradoc, the former consisting of transition limestone, the latter on its south-eastern slope of grey-wacké and grey-wacké slate, and extending from Church-Stretton to the Wrekin.

The *upper regions* of the formation of transition limestone, which is perhaps the most recent member of the transition series of Werner, consist of shale alternating with extensive beds of stratified limestone. The lowest of the calcareous strata are thin, and alternate with shale. Upon these repose thicker strata of more compact limestone, often of a dull-blue colour, and sometimes having a tendency to lie in rubbly knotted masses, rather than in flat continuous slabs. Occasionally the limestone is so charged with sand, as to pass into calcareous sandy flag-stone. The beds are often dolomitic, which is indicated by the straw-yellow or dark-pink colour, and by the sandy or glimmering aspect of the rock. This happens in the western escarpment of Bryerry-hill on the side of Aston Ingham, to the south-west of Newent. The transition limestone abounds with organic remains, viz: trilobites, orthoceratites, and the catenarian and other corals, which agree precisely with those of the limestones of Malvern, Dudley, and Wenlock-edge.

The limestone accompanies the shale irregularly in the range that extends from Flaxley to the Marcle-hills and Stoke Edith. This range widens in its progress northward. Its southern apex at Flaxley is contracted in breadth to a few hundred yards; near Hereford it is about 5 miles broad. Its total length from south to north is nearly 20 miles. Beyond its northern extremity at the distance of more than a mile, we find the insulated hill called Shucknell-hill, an outlying mass of transition limestone, dipping very rapidly and outwards on every side, conformably to the slope of the hill, beneath old red sandstone. The Marcle-hills are almost continuous with the similar range of transition limestone, which reposes on the western flank of the Malvern Hills, and extends northwards to Abberley; since the ranges are separated only by the vale of Ledbury, which is 6 miles broad, and consists of old red sandstone.

The oldest rocks which the Marcle range touches in its progress southwards, are the grey-wacké strata of May-hill; on approaching the northern extremity of which it bifurcates, near the village of Aston Ingham. Around both sides of May-hill, the strata of shale and limestone, always highly inclined and sometimes perpendicular, form a continuous mantle, until their western skirt, having passed beyond the grey-wacké, becomes depressed at the village of Flaxley, below the level of the newer red sandstone, and is buried beneath it. Overlying strata of newer red sandstone, close over the eastern skirt at the village of Huntley, and for a short space come into contact with the grey-wacké itself. It is probable, that beneath this sandstone, the shale and limestone embrace the roots of the mountain, and are continuous from Huntley to Flaxley.

Above the calcareous strata the shale becomes gradually coarser, and harder; it changes in colour from the prevailing greenish-brown to red, and passes insensibly into the lowest strata of the old red sandstone formation. This upper portion of the shale, which immediately covers the transition limestone, is known in the Shropshire coal-field by the name of *die-earth**; and with this die-earth, the upper beds of the range between Ledbury and Malvern agree both in character and position.

A similar series of beds to those which we have now described, as belonging to the transition limestone on the north-eastern border of the Forest of Dean, is found also on its south-western frontier, and there emerging from beneath old red sandstone, exhibits the lowest formation that occurs between this basin and that of South Wales. These opposite points, at which the lowest strata are protruded, determine the natural limits of the basin that we are now describing.

It is to the west and north-west of Usk, over an area extending in length from N. to S. about 7 miles, and in breadth from E. to W. about 3 miles, that the transition limestone appears. Its northern extremity lies between Ragland and Abergavenny, at Clytha Castle, where a section of the hill by the road-side, shows its dip to be to the north-east. It is visible also on both sides of the road from Clytha Castle to Usk, maintaining the same dip as far as that town, which stands upon it. In the hills to the west of Usk, which are situated near the axis of this group, the dip is both rapid and variable; on the southern and western limits of the group, it dips outwards on either side, and sinks under the conformably inclined strata of old red sandstone, which mantle round it.

It consists principally of thin laminated strata of tender argillaceous slate, of a greenish-grey colour, containing subordinate beds of similarly coloured sandy slate, and of argillaceous limestone, abounding for the most part, with the characteristic organic remains of this formation, and particularly with orthoceratites. The thickness of the calcareous beds is very variable, that of the separate strata seldom exceeding 2 feet. The calcareous matter is often

* The upper portion of the transition limestone shale, has acquired this appellation, because in Shropshire, the coal-measures die or terminate on coming into contact with it. This contact arises in the coal-field of Coalbrook Dale, from the total absence of the two formations of mountain limestone and old red sandstone; occasioning the lowest of the coal-measures, to repose immediately on the uppermost beds of the formation of transition limestone. In the coal-field of Dudley, there is a similar contact.

disposed in balls and knobs of a lead-blue colour, imbedded in shale. Where the limestone alternates with sandy beds, it passes gradually into a calcareous sandstone.

3. Old red sandstone.

The old red sandstone, whose limits are so restricted in other parts of England, here occupies an extensive area, being a continuation of that greater tract, over which, in Brecknockshire and Herefordshire, the same formation is spread. The space which it here covers, its great thickness, its high inclination, the abrupt character of the surface over which it prevails, and the consequent display of its strata in many natural sections, present in this district advantages for studying the formation, which are not to be met with elsewhere in South-Britain. In the neighbourhood of Mitchel Dean, according to the section of Mr. Mushet, which we ourselves have verified, the total thickness of this formation, interposed conformably between the transition and mountain limestone, is from 600 to 800 fathoms.

It appears practicable to subdivide the formation into three distinct portions. In the *lower portion*, compact micaceous slaty sandstone predominates, approaching in character to the coarser varieties of grey-wacké slate, and occasionally becoming a red calcareous slate. The abundance of highly-indurated ferruginous clay, and of mica, in the sandy beds of this formation, renders them harder and more fissile than those of the newer red sandstone; and thereby qualifies them for flag- and paving-stone; but at the same time renders them a very indifferent free-stone. These lower beds, as they approach the transition limestone, contain the organic remains of that formation. The *middle portion* of the old red sandstone consists of marl or marly sandstone, through which are disseminated irregular, concretional, pebble-shaped, nodules of limestone, giving to the rock the appearance of a breccia. These masses occur in irregular proportions, and vary in size from that of a pea, to blocks of many tons. This pseudo-conglomerate is generally known in Herefordshire by the name of *cornstone*. For a minute account of the Herefordshire cornstone, and for the characters which distinguish it from a true breccia, we refer to a note in Professor Buckland's paper on the Lickey Hill, page 512, vol. 5, old series, Geol. Trans.

The cornstone may be seen at the western base of the Kyming-hill, to the east of Monmouth, and occurs extensively between Monmouth and Abergavenny, and in the hills of old red sandstone, to the east of Newport, on the road to Christchurch, in Monmouthshire. It is not unfrequently worked for lime; but from the prevalence of limestone of better quality in the neighbourhood of the Forest of Dean, it is there an object of less importance than in many parts of the neighbouring counties, where it often affords the only supply of that necessary material.

The *upper portion* of the old red sandstone, is characterized by the presence of siliceous conglomerate containing siliceous pebbles. This position of the conglomerate in the old red sandstone, is verified by numerous sections along the banks of the Wye, from Ross to Monmouth, and also by the fine section in the hill immediately to the west of Mitchel Dean. The summit of this hill presents the millstone-grit or lowest grit of the coal-measures; the middle region shows the outcrop of the mountain limestone, from beneath which, towards the base, the conglomerate beds of the old red sandstone emerge in a manner equally distinct. The summits of the loftiest hills near Monmouth, abound with enormous blocks and small insulated tors composed of this conglomerate, of which the rocky projections on the summit of the Kyming-hill, and the insulated tor, at no great distance from it, in the direction of the Forest, called the *Brick-stone,* and usually mistaken for a druidical monument, are examples. This conglomerate, also forms the upper stratum of many of the highest ridges between the Wye and Usk. It is applied extensively to the fabrication of millstones near Monmouth, and on the banks of the Wye.

Beds of red and variegated soft, slaty, marl, and marly sandstone, occur indifferently from the top to the bottom in every part of this formation. These marly beds are often precisely similar, both in colour and substance, to those of the newer red sandstone; but in the older formation, they are usually more distinctly slaty, and alternate more rapidly with thin layers of sandstone-slate. We have before alluded to the remarkable fertility of these marly beds in the old red sandstone, in Monmouthshire and Herefordshire.

The old red sandstone encircles the Forest, with a ring of very elevated ground, whose long and lofty ridges on the eastern frontier overhang the valley of the Severn. The trough of the river, is filled for the most part with the horizontal formations, but the sandstone is exposed in one short interval, between the villages of Lydney and Blakeney, there forming a range of cliffs along the edge of the water to the distance of 2 miles, which face the similar rocks occurring on the opposite bank, to the south-west of Pyrton Passage-house. On the western side of the Forest, the old red sandstone is traversed from Ross to Tinterne, by the defiles of the Wye, which are so steep and narrow as scarcely to be perceived at a small distance from the river. To the west of the river, the mountain chain of sandstone is nearly continuous, and increases in height as it advances, until it forms the ridge of Pencamawr between Monmouth and Newport. Not far from this ridge, but not immediately connected with it, on the road between Newport and Chepstow, near Penhow, are two very considerable and boldly pointed mountains of this rock. The elevations attained by the summits of the mountains of sandstone in this neighbourhood, vary from 800 to 1300 feet above the sea.

4. Mountain limestone.

This important and extensive series of calcareous beds, is distinguished from transition limestone, rather by its position, than by any very wide difference in its general character, or organic remains.

According to the measurements of Mr. Mushet, to whose section we refer for an account of the beds belonging to this formation in the Forest of Dean, the total thickness of the mountain limestone is about 120 fathoms. The mountain limestone of this basin agrees in all its general characters with that of Somersetshire and Gloucestershire; we may notice however, as peculiar to it in the Forest of Dean, certain subordinate beds, which are so charged with oxide of iron, as to have been worked as an iron-ore for many centuries.

The zone of limestone, belonging to this basin, is from a furlong to a mile in breadth, according as the dip of the strata is more or less rapid. The angle of dip on the northern and western border is often only 10°, but on the eastern it frequently amounts to 80°. The calcareous zone suffers only one short interruption, scarcely 3 miles in length, on the south-eastern border, near Lydney, where in consequence of a fault the limestone disappears, and the coal-measures are seen in contact with the old red sandstone *. The line of this fault is indicated by a series of springs, which break out at the ponds in the Lydney valley, exactly between some coal-pits and a large flag-stone quarry, worked in the old red sandstone. From Coleford, on the south-western border of the zone, a branch of limestone, lying in a trough of old red sandstone, proceeds southwards to the neighbourhood of Tinterne. This calcareous branch contains a small insulated coal-basin not exceeding a mile in length, situated half-way between Tinterne and the village of Wollaston. Below Tinterne, the limestone forms the romantic cliffs which skirt the defile of the Wye on either side, as far as the confluence of that river with the Severn. Near Chepstow, are contortions in this limestone, which have been represented by Dr. Macculloch, in a drawing presented to the Geological Society. The limestone on the right bank of the Wye, extends as far as the Crag whereon Penhow Castle stands. It is bounded on the south by the marshes

* A fault, suddenly bringing the same two formations into contact, has already been noticed at Clapton on the northern foot of Leigh Down; and another, producing similar effects, is found at Stanley, on the right bank of the Severn, between Bridgenorth and Bewdley.

of Caldecot Level, and on the south-east it dips away gradually from the old red sandstone of Penca-mawr, and sinks under the overlying formations, finally disappearing beneath the bed of the Severn, between the New Passage-house and themouth of the Wye.

5. Coal-measures.

The aggregate thickness of the coal-measures amounts, according to Mr. Mushet, to about 500 fathoms. 1. The lowest beds, which repose on the mountain limestone, are about 40 fathoms thick, and consist here, as in the basin of Bristol, of a red siliceous grit, alternating with conglomerate used for mill-stones, and with clay occasionally worked for ochre. 2. These beds are succeeded by a series about 120 fathoms thick, in which a grey gritstone predominates, alternating in the lower part with shale, and containing 6 seams of coal. The grits are of a fissile character, and are quarried extensively for flag-stone, ashlers, and firestone. 3. A bed of grit, 25 fathoms thick, quarried for hearth-stone, separates the preceding series from the following, 4. which is about 115 fathoms thick, and consists of from 12 to 14 seams of coal alternating with shale. 5. To this succeeds a straw-coloured sandstone, nearly 100 fathoms thick, forming a high ridge in the interior of the basin, from Serridge-hill, behind Churchway Engine on the north, to below Park-end on the south. It contains several thin seams of coal, from 6 to 16 inches in thickness. 6. On this reposes a series about 12 fathoms thick, consisting of 3 seams of coal alternating with shale. 7. This is covered by alternating beds of grit and shale, whose aggregate thickness is about 100 fathoms. They occupy a tract in the centre of the basin, about 4 miles long and 2 miles broad, between the Ancient Hall called the Speech-house, in which the courts held under the forest laws were formerly convened, and Foxes' Bridge. It is difficult to establish the identity of beds in different coal-basins, even though contiguous. Mr. Mushet regards the grey rock No. 2. as holding the place of the Pennant rock of the basin of Bristol: we are inclined, however, to consider the sandstone No. 5. as the equivalent of the Pennant; and to refer the three series, Nos. 2, 3, and 4, to the lower coal-shale, and Nos. 6 and 7 to the upper coal-shale of that district.

Vertical Section of the Strata of the Forest of Dean, constructed from actual sinkings and from observations made at the surface by D. Mushet, Esq. Honorary Member of the Geological Society.

			Fath.	Ft.	In.			
No. 7.	Unexplored measures		100	0	0	100	0	0
No. 6.	*Woorgreen's coal*		0	2	6			
	Cliff and sand-rock		4	0	0			
	Small coal		0	0	10			
	Cliff and sand-rock		4	0	0			
	Small coal		0	1	4			
	Cliff and sand-rock [in the middle of this is found the Arlyn mire iron-stone used at Park-end furnace.]		3	0	0	11	4	10
No. 5.	Straw-coloured sandstone, mixed with thin beds of red marl		77	0	0			
	Coal	These seams have been observed in Mire-brook ditch, but have not been worked.	0	1	4			
	Straw-coloured sandstone		5	0	0			
	Coal		0	1	4			
	Straw-coloured sandstone		5	0	0			
	Coal		0	0	10			
	Straw-coloured sandstone		2	3	0			
	Coal		0	0	10			
	Straw-coloured sandstone		2	3	0			
	Coal		0	1	4			
	Straw-coloured sandstone		5	0	0	97	5	8
No. 4.	Stone bind and dark-coloured cliff		30	0	0			
	Little-delf coal		0	0	4			
	Cliff		4	0	0			
	Crow coal		0	2	0			
	Cliff and stonebind		4	0	0			
	Smith's coal		0	2	6			
	Cliff and stonebind		1	3	0			
	Foot coal		0	1	6			
	Cliff and stonebind		7	0	0			
	Park-end high-delf coal		0	3	6			
	Cliff and stonebind		1	3	0			
	Shefnil's coal		0	0	6			
	Cliff and stonebind		5	0	0			
	Starkey coal		0	1	10			
	Cliff and stonebind		2	0	0			
	Shefnil's coal		0	0	6			
	Cliff and sand-rock		5	0	0			
	Rocky coal		0	2	0			
	Cliff and stonebind		2	0	0			
	Breadless coal		0	1	4			
	Cliff and stonebind		10	0	0			
			74	4	0			
	Carried forward					209	4	6

		Fath.	Ft.	In.			
	Brought forward				209	4	6
No. 4 continued.	*Upper Churchway or Oakenhill coal* (These two delves unite and form the high delf at Churchway and Bilston.)	74	4	0			
	Cliff and stonebind	0	2	3			
	Lower Churchway coal	6	0	0			
	Cliff and stonebind	0	2	3			
	Strong straw-coloured rock	7	0	0			
	Cliff and stonebind	2	0	0			
	No coal	1	3	0			
	Stone, stonebind, and dark-coloured cliff	0	1	6			
	Brazilly coal	22	3	0			
		0	2	0			
					115	0	0
No. 3.	Brazilly rock, of which the hearths for charcoal furnaces seem formerly to have been made	25	0	0			
					25	0	0
No. 2.	*Nameless delf coal*	0	0	4			
	Nag's-head hill rock	40	0	0			
	Nag's-head or Yorkley coal	0	2	9			
	Grey rock or Pennard	25	0	0			
	Whittington's delf coal, found only in Bream district	0	2	6			
	Grey rock	22	3	0			
	Coleford high delf coal, containing lead-ore at Cinderford	1	0	0			
	Argillaceous shale, with iron-stone	8	0	0			
	Trenchard grey rock	13	0	0			
	Upper Trenchard, or spider delf coal	0	3	0			
	Grey rock, interspersed with party-coloured marls	7	3	0			
	Grey rock, very sharp, coarse and granular, alternating with flesh-coloured clay, fire-clay, and cliff	4	0	0			
	Lower Trenchard coal	0	2	6			
					122	5	1
(Millstone grit.) No. 1.	Fire-clay and coarse sharp red gritstone, or Farewell rock	5	0	0			
	Red sandstone, with layers of red and white indurated marl, falling to pieces by exposure to the weather. It contains cobalt towards the bottom at Mitchell Dean	12	3	0			
	Upper limestone bed	5	0	0			
	Pure siliceous red grit, with two beds of pudding stone	15	0	0			
					37	3	0
Coal-measures	Total				510	0	7

			Fath.	Ft.	In.			
Mountain limestone.	Upper limestone shale.	Porcelain limestone	3	0	0			
		Dark grey limestone	2	0	0			
		Ball limestone in clay matrix	4	0	0			
		Small blue beds	0	3	0			
		Greyish-blue limestone with purple joints	17	3	0			
		White limestone	3	0	0			
		Iron ore and marl, from 5 fath. to	8	0	0			
	Limestone.	Great white-cliff bed of limestone	40	0	0			
		Yellow clay limestone	7	3	0			
		Great blue limestone, oolitic to the N.W. of Coleford, with clay	4	0	0			
		Sparry limestone oolitic near St. Briavels, and slightly so near Coleford	5	0	0			
		Brownish-red limestone, with iron ore	4	0	0			
		Swan-pool, or Cherry-orchard limestone	12	3	0			
	Lower limestone shale.	Beds of brownish-red marl	2	3	0			
		Straw-coloured sandstone	4	0	0			
						117	3	0
Old red sandstone.		Upper gritty bed of the great red formation	20	0	0			
		Great plum-pudding stone	10	0	0			
		Great red sandstone (Best section between Ross and Perriston-hill on the road to Ledbury.) from 600 to	800	0	0			
		from 630 to				830	0	0
Transition limestone.		Limestone as seen cropping out from beneath the great red sandstone at Longhope and Huntley.						

Chapter IV.—ON THE OVERLYING STRATA.

1. Newer red sandstone.

Conglomerate, red sandstone, and red marl, together constitute the formation to which the terms *red ground* and *red marl* have been applied, and which we have called the *newer red sandstone*. The average total thickness of this formation in the south-western coal-district, is about 200 feet, which is not much more than one fourth of the thickness, which it is known to attain in the north-eastern parts of England.

The lowest member of this formation is:

§ 1. The dolomitic conglomerate *.

The immediate covering of the older rocks is usually a conglomerate, composed of fragments of those rocks united together by a cement, which in most cases consists of dolomite, or dolomite blended with carbonate of lime, but not unfrequently of carbonate of lime only, of clay, or of fine iron-shot sand.

The fragments vary in size, from the finest grains to bowlders of 3 feet and upwards in diameter, and are for the most part rounded; though sometimes very slightly so, when the parent rock *in situ* is close at hand. The fragments which it contains in the greatest number, are those of the inclined strata, the nearest adjacent. Thus in the overlying conglomerate, which skirts the Quantoc hills, the most abundant pebbles are those of the transition rocks, of which those hills consist; and throughout the coal-district here treated of, when the principal surrounding chains consist of mountain limestone, fragments of that limestone predominate; but we also find fragments of old red sandstone, and quartzose pebbles, derived probably from the older conglomerates in the old red sandstone or millstone grit. Fragments of coal-sandstone are extremely scarce, as might be expected from their friable texture. This conglomerate has evidently been spread over the surface, as it formerly existed, in the state of loose gravel, like the diluvian gravel, which at a later period has been scattered over the earth. The conglomerate occasionally becomes fine-grained, and so charged with the matter of the cement, that it passes into a tolerably compact dolomite, bearing no traces of mechanical origin, and then closely agrees in character with the yellow magnesian limestone of the north-eastern counties of England †. Beds of yellow dolomite, thus strongly characterized, are found prevailing over tracts of considerable extent, particularly at Portishead-point and beneath the ruined church of Old Clevedon on the shores of the Bristol Channel, in the low cliff to the north of the Old Passage-house on the right bank of the Severn, and on the north-western and northern limits of the Bristol coal-basin, at the villages of Almondsbury and Tortworth. When we consider how abundantly dolomite occurs in mountain limestone, and that in the district here treated

* This conglomerate has been ably described in the 4th volume of the Geological Transactions by Dr. Bright, Mr. Warburton, and Dr. Gilby. Mr. Warburton has most correctly considered it as equivalent to the yellow magnesian limestone of the north-eastern counties of England.

† This rock, as it occurs in Nottinghamshire and in the north-eastern counties, being the first in which the late Smithson Tennant discovered the presence of magnesia, has usually been termed, *par excellence*, the magnesian limestone. In England, however, so many of the older calcareous formations are occasionally dolomitic, and on the continent so many of the more recent ones, that the term has become equivocal, unless we connect with it in each particular case the name of the formation to which it belongs.

of, fragments of mountain limestone are usually the principal ingredient in the conglomerate, it seems natural to consider the dolomite in the limestone, in the state of finely worn debris, as the origin of the dolomitic cement *.

The conglomerate is remarkable, particularly in the neighbourhood of Wells, for the occurrence of small irregular cavities, from an inch to a foot and upwards in diameter, which are lined, and sometimes filled, with concentric plates, resembling in their structure those of an agate, and consisting of calcareous spar, coarse chalcedony, and crystals of quartz. These geodes are called, from their shape, Potatoe stones. They are found of smaller dimensions in the compact dolomite at Old Clevedon, and are there almost wholly siliceous, being, in fact, coarse agates, hollow within, lined with crystallized quartz, and sometimes containing crystals of sulphate of strontia. The geodes found in the neighbourhood of Clifton have been noticed in the 2nd chapter.

Besides the smaller cavities, in which the geodes have been formed, the conglomerate abounds with long, low, irregular vacuities; which usually have a communication with one another, and thus extend under ground over large tracts of the rock. These caverns have probably been occasioned by irregular deposits of fine loose sand, which has subsequently been removed from its place, and thrown out at the surface by the action of springs. Nests of sand, irregularly dispersed after the manner of these cavities, are frequently found in the interior of the conglomerate.

Any one of these caverns, in connexion with those adjacent, forms a vast subterranean reservoir, which on being penetrated (as often happens) by a coal-shaft, overwhelms the miner with torrents of water. To exclude this discharge, cylindrical shafts of masonry are constructed, of sufficient strength to resist the pressure of a column of water, equal in height to that of the highest level at which the water stands in any part of the chain of caverns intersected. These shafts of masonry are carried to as high a level as the water will rise; and that is frequently to the surface, so as to form an overflowing well. Since water always carries with it a quantity of air, the explosion of which when compressed might be attended with much danger, the

* This theory may not be considered as applicable to the yellow dolomite of the north-eastern counties, on account of its fine texture and regular stratification; yet even there the dolomite is frequently associated with a breccia [vide Wynch. Geol. Trans., vol. iv. p. 6.]; and perhaps it deserves remark, that, after running parallel to the great chain of mountain limestone, which, with little interruption, traverses the counties of Durham, York, and Derby, the dolomite suddenly becomes coterminous with that limestone on the south, and does not reappear in other parts of England, except in the vicinity of similar calcareous chains.

air is allowed to escape at the angles between the shaft and the square pit in which the shaft is constructed.

The quantity of water discharged at the occasional piercing of these reservoirs, had led not long since to the belief, that an inexhaustible subterranean river was continually traversing them; and accordingly, from the Avon to the collieries of Radstock a canal was cut, for supplying which with water it was calculated that this river would suffice. In a few days after the engine-pumps had begun to work, the water failed; since, after exhausting the reservoir, an additional supply could only be derived from the slow percolation of rain-water through the incumbent strata. The canal has in consequence become useless, and a rail-road has been substituted for it.

The conglomerate is often metalliferous, yielding occasionally some galena, and more frequently calamine, in some abundance. These ores occur sometimes in small veins, but are usually disseminated through the rock, particularly when it is charged with calcareous spar. The galena, when thus disseminated, occurs in angular fragments; it appears pretty extensively in this form in the compact, yellow dolomite of Old Clevedon and Portishead. Much of the calamine has been formed stalactitically around dog-tooth spar, and is now found in the shape of hollow casts and pseudomorphic crystals, in consequence of the calcareous matter having perished. These ores are probably of simultaneous origin with the conglomerate itself, having been derived mechanically from the debris of metalliferous veins which traversed the mountain limestone. We may be induced however to hesitate in adopting this theory, by reason of the metalliferous character of the Zechstein and Alpine limestone, the geognostic equivalents on the continent of the dolomitic conglomerate of England.

Sulphate of strontia occurs abundantly in the conglomerate in the vale of Westbury. The thickness of the conglomerate is very variable, often changing suddenly from many fathoms to a few inches, as might naturally be expected in a stratum which was once an accumulation of derivative gravel. Thus it generally forms a thick bank or talus near the base of those hills from whose debris it has been derived; while at a distance from them it grows thinner, and at length wholly disappears. Sometimes it hangs on the sides of the mountain chains at considerable elevations, covering their truncated escarpments or posterior slopes; occasionally it fills up partial depressions in the high table-lands at the very summits of those chains. Not unfrequently, when the talus-shaped strata have been deeply furrowed by diluvian action, the remarkable appearance has resulted of large insulated masses of conglomerate, resting unconformably, at irregular elevations, on the sloping planes and escarpments of the mountain chains. Mr. Warburton has thus accounted for the appearance of those insulated masses of conglomerate which had been observed by Mr. Tennant on the southern hangings of the Mendips. In the narrow valleys, having a base of old red sandstone, which lie inclosed within ridges of mountain limestone, the intervals between the ridges are generally occupied by the conglomerate, which conceals with its horizontal beds the fundamental rock. Striking examples of this may be seen in the valleys of Shipham on Mendip, and of Westbury near Bristol.

Associated with the conglomerate, there often occurs a sandstone of so fine and compact a grain, as to assume the character of chert. It occurs interstratified with the conglomerate on the road between Pitcot and Holcombe, at the new colliery between Chilcompton and Stratton, and in a quarry by the side of the lane leading from that colliery to Stratton, at the entrance of the village. Nearly adjoining the places here enumerated, on the south-west, and to the south of Emborrow mere, is an insulated tract * $\frac{3}{4}$ of a mile long, and $\frac{1}{4}$ broad, in which a similar chert is found. It is bounded by conglomerate and mountain limestone: but there are no sections which distinctly show its relations to those rocks. In all these places the chert is destitute of shells, except at Emborrow, where it contains fragments of encrinites; but those are probably derived from the debris of mountain limestone.

The chert found on the elevated platform above East Harptree, and on the neighbouring summits on either side of the Tar Hall valley, is of so peculiar a character, that it is with some hesitation that we refer it to the dolomitic conglomerate.

The situation and extent of this platform, which is traversed by the road from the Castle of Comfort to East Harptree, have been already described in the 2nd chapter. The rock which crowns the platform is a compact cherty sandstone, which occasionally passes into a conglomerate, consisting of fragments of old red sandstone imbedded in a cherty cement. This cherty sandstone abounds with heavy-spar, and is sometimes very calcareous. It here contains shells belonging to the genera Ammonites, Modiola, Pecten, Tellina, and Plagiostoma (2 species), which in general are reduced to the state of hollow casts, partially filled in some instances with heavy-spar; the shell itself is sometimes chalcedonized. The summit of the platform is covered with blocks of the chert, which appears also in numerous excavations forming a thick horizontal bed †, reposing on ochreous sand. The whole surface is

* There is a remarkable swallet-hole in this tract.

† The Druidical circles of Stanton Drew, about 9 miles distant to the north, are principally constructed of this cherty sandstone.

scarred with deep, conical, and often very extensive hollows, which probably are ancient ochre-pits; the largest are those on the east of the Harptree road; to the west of the road, the sand beneath the chert is still worked for ochre. The southern border of the platform, near the Castle of Comfort, reposes immediately on mountain limestone; but with this exception throughout the whole escarpment of the platform, horizontal strata of dolomitic conglomerate, of the ordinary character and appearance, may be traced beneath the ochreous sand and chert.

The two hills on either side of the Tar Hall valley, which, except at their very summits, consist of old red sandstone, are crowned with blocks of the cherty sandstone, very compact, including fragments of the old red sandstone, and abundantly charged with heavy-spar. On the summit opposite to Egarhill on the south, we find many conical pits, which were probably sunk in order to obtain calamine from the conglomerate beneath the chert.

We shall now proceed to trace the extent of the conglomerate, and to describe some of its more remarkable local appearances in the district.

It skirts the whole southern side of the Mendip chain from Shepton Mallet to the Bristol Channel, spreading itself out to the breadth of more than a mile in the neighbourhood of Wells, but forming a narrow band towards the west, where bordered by the marshes of the Axe; it appears also in some insulated hills which project above the surface of these marshes. Some handsome pillars in Wells cathedral, having the character of a brecciated marble, have been quarried from this rock. In the neighbourhood of Wells, and at Bleydon near the Bristol Channel, it forms a beautiful breccia, called *wonder-stone*, consisting of yellow transparent crystals of carbonate of lime, disseminated equably through a dark-red earthy dolomite. The cavern of Wokey hole, and the chasm flanked by mural precipices by which it is approached from below, are excavated in the conglomerate. It attains in the neighbourhood of Wokey a considerable elevation along the hangings of the limestone chain; and in the frequent insulated masses of it, which remain scattered along the slopes of the chain between Wokey and Cross, it has left traces of its former extent at the same high level. On the high table-land in the centre of the Mendip chain, and at the opposite extremities of the old red sandstone ridge north of Priddy, are two extensive insulated masses of the conglomerate, which probably occupy hollows in the lower limestone-shale. The eastern of these masses is at Chewton minery, and comprehends also the Priddy mineries; the western is at Highdon farm. Considerable mines of lead and calamine were formerly worked in and near the former of these masses; the calamine was worked in conglomerate; the lead principally in mountain limestone.

We have already described in the 2d chapter the elliptical valley which extends from Roborough to Loxton. The conglomerate is here worked, both at Roborough and Shipham, for calamine, which is found crystallized, compact, and pseudomorphic. Some galena is also raised. These mines, though on a small scale, are the principal ones now worked in Mendips.

On the northern side of the Mendip chain, we find the conglomerate near Mells, at the eastern extremity of the southern coal-tract, concealing the junction of the coal-measures and the mountain limestone. It forms one of the most striking features in the scenery of Mells park, and abutting against the truncated edges and sloping planes of strata of mountain limestone, flanks the gorge of the Nettlebridge river from Mells house to a little below the village of Mells, with steep banks and mural precipices more than 50 feet high. The fragments which it here contains are enormous. At the western extremity of the southern coal-tract, it crowns with mural precipices the abrupt sides of the valley from Nettlebridge to Emborrow, resting in vast horizontal masses on the coal-measures, which are only laid bare in the bottom of the vale. A projecting precipice of conglomerate, called the Bulwarks, has been fortified on its northern side, which alone was accessible. At Chewton Mendip, and at East and West Harptree, the conglomerate lies in banks of enormous thickness, and at the two latter villages has formerly been exceedingly productive of calamine. From West Harptree it continues to maintain a considerable thickness along the whole northern base of the Mendip chain, by Burringdon and Banwell to Uphill on the Bristol Channel. We have already noticed the occurrence of the conglomerate at the eastern base of the hills of Worlebury and Woodspring, and at Redhill on the southern flank of Broadfield down. It is particularly well displayed near Butcombe at the bottom of the deep valleys which there cut through hills of lias: these valleys also exhibit striking sections of the superior horizontal strata. It skirts the valley of Nailsea along the north-western base Broadfield down, and occurs less abundantly along the opposite slope of Leigh down. Towards the western extremity of the latter, and on its south-eastern slope, immediately above the village of Clevedon, we find insulated masses of a buff and red dolomite, resting on the limestone. Similar masses occur further eastwards. The conglomerate has previously been mentioned as lining the coast from Clevedon to Portishead point; it is also found at Portishead and Portbury, and, in the interval between these villages and the Avon, it partially conceals the subjacent old red sandstone. It crosses the Avon to the west of Cook's Folly, and constitutes the upfilling of the vale of Westbury, between the opposite ridges of Durdham and King's-Weston downs. We have before described it as reposing on the mountain limestone on the ascent of the new road from St. Vincents rock to Durdham down. Its appearance between this point and Redland, to the south-east of Durdham down, and in the vale of Westbury, has been fully described by Dr. Bright. Further to the north it is seen at Henbury and Almonsbury, and thence along the exterior base of the calcareous boundary of the coal-basin, by Thornbury and Tortworth to Wickwar. Within the coal-basin it appears on the western side, emerging from beneath beds of lias from Bristol to Titherington, and on the eastern side, reposing on the inclined strata at Wick rocks.

The conglomerate is found pretty extensively along the channel and on the left bank of the Severn, to the distance of 2 or 3 miles on either side of the mouth of the Wye. At the New Passage beds of conglomerate and dolomitic sandstone occupy the low shores on both sides of the river, and also compose those extensive flats called the Welsh and English shores. The largest of these, which becomes uncovered at half-ebb, is nearly 3 miles long and 1 broad. At low-water it forms, together with two similar flats, one to the north, the other to the south of it, a bar almost entirely across the Severn. These shoals are intersected by channels of dangerous navigation, through which the tides rush with enormous velocity. Their northern portion is composed of conglomerate, their southern of a yellow dolomitic sandstone, forming a link between common yellow dolomite and the newer red sandstone.

At Chapel rock, the promontory close to the Old Passage-house at the mouth of the Wye, an interesting section is displayed of the junction of the conglomerate with mountain limestone. In the low cliff, which extends half a mile to the north of the Passage-house, the conglomerate passes into a homogeneous rock of dolomite, which, at the lofty precipice of Annards cliff, is covered by superstrata of red marl and lias. At Tidenham the conglomerate reposes on the basset edges of mountain limestone; at Wollaston upon old red sandstone. Small flats and shoals, composed of the conglomerate and dolomitic sandstone, occur in the bed of the river for 4 or 5 miles above the Passage-house; these rocks have of late been taken in great quantities from the river near Tidenham, for building the foundation of the new bridge at Chepstow.

§ 2. That member of the newer red sandstone formation, which immediately reposes on the conglomerate, consists of a friable red, white, or yellowish sandstone, which sometimes, where it passes into the conglomerate, is abundantly charged with dolomite. This sandstone is seldom hard, tough, and fissile enough for tile- or flag-stone. It is usually characterized by the absence of distinct stratification, and by the presence of irregular partings and lines of false stratification, running obliquely across thick beds of uniform texture, which afford massive blocks of freestone. In a country, however, where so much better building stone is at hand, it is seldom employed for architectural purposes ; though formerly used at Bristol in the walls of the cathedral and other ancient edifices, and recently in the construction of the docks. The want of durability of this stone is lamentably attested by the present mouldering state of the cathedrals of Bristol, Chester, and Carlisle, and of the churches at Coventry, the decay being occasioned, in some instances, by the salt or gypsum which the rock contains. Near Ratcliff church, there is a series of catacombs in this rock, resembling on a small scale those of Paris, from which stone has been extracted in ancient time for the buildings in the city. This sandstone may be studied most advantageously in the neighbourhood of Chew Stoke and Chew Magna, and in the new cut at Bristol. At the latter place a cellular variety of it has been found, the small cavities of which are lined with sulphate of strontia.

§ *3*. Upon the sandstone repose beds of red and variegated marl, which is not laminar like that of the old red sandstone, but globular in structure. The marl in the upper part of the series becomes green, and then contains subordinate layers of red and green marl-stone, approaching in character to lias, and gradually passing into it. The marl sometimes contains nodules, and is sometimes traversed by veins of gypsum and sulphate of strontia. Both these minerals are found in the marl of Aust cliff. The lowest bed of marl is there traversed by tortuous and curiously reticulated veins and beds of gypsum, and is cut by two nearly vertical veins of sulphate of strontia, which is sometimes fibrous. We shall have occasion to revert in the sequel to this cliff, when describing the lias by which the red marl is there covered. It directly faces the opposite cliff of Annards on the right bank of the Severn, where we find a corresponding succession of beds of red marl crowned by lias. In the hill to the north-west of Bitton, and at Tortworth, the marl contains large blocks of sulphate of strontia, which is there called *salt-stone*. The sulphate of strontia occurs in the same geological situation at Knaresborough in Yorkshire and on the coast of Glamorganshire.

The two preceding members of the newer red sandstone formation, the red sandstone and the red marl, are of far inferior interest to the conglomerate, as presenting wherever they occur the greatest uniformity of character ; we refer, therefore, for the details of their geographical extent to the map which accompanies this memoir.

They are found extensively distributed within the Bristol coal-basin, appearing along the boundaries of the several denuded coal-tracts. Between the central coal-tract of Pensford and the southern coal-tract of Nettlebridge they appear in every valley emerging from beneath elevated platforms of lias and oolite, and are here repeatedly pierced by shafts which descend to the coal. The sections afforded under these circumstances are of the highest geological importance, since they clearly display the relation between the newer red sandstone and the coal-measures, and establish with the utmost precision the distinction between the newer red sandstone and the old, which from their similar colour and ingredients are so very liable to be confounded. The newer red sandstone, exhibiting throughout its whole course an identity of character and composition, is absolutely continuous from the points in this district, where it rests unconformably on the coal-measures, to the plains of Salop, where its relations to the coal-measures have appeared obscure to the most acute geologists.

The red sandstone and red marl occur intermixed with the conglomerate, along the entire bed of the Severn, from Westbury cliff on the north-east to the mouth of the Usk on the south-west, with the exception of the narrow interval of old red sandstone and transition limestone near Pyrton Passage, and of two or three projecting crags of mountain limestone previously noticed. To the south of the Forest of Dean, they form the base of the extensive marshy tract, called Caldecot Level, which lies to the south of the high range of Pencamawr, between the mouths of the Wye and the Usk. Here the red marl is seen beneath the lias, in the small hill of Goldcliff, as it is about 3 miles to the north of Goldcliff, on the further side of a marsh, in a low range of hills, about 3 miles long, running through the parish of Llanwern. The red marl at the northern extremity of this range abuts against the old red sandstone, which forms part of the southern base of Pencamawr. Still further to the south, the red marl constitutes the flats between the Usk and Taaf. The occurrence of the newer red sandstone formation in the southern part of Glamorganshire, has been noticed in the introductory chapter.

The red marl and sandstone sweep along the banks of the Severn, to the east of the border of the Forest of Dean, and to the east of the ridge of transition rocks which connects May-hill with the Marcle hills. They fill the trough, marked by the Ledbury canal, which divides the Marcle hills from the southern extremity of the Malverns, and occupy the whole valley between the Malverns and the Severn, except in those few spots which are covered by superstrata of lias.

2. Lias.

The lias consists of strata of blue slaty clay, which, in the lower part of the formation, alternate with beds of limestone.

The aggregate thickness of the formation, when greatest within the limits of our district, may be fairly estimated at 50 fathoms. This is reduced in many places to 25 fathoms, and, near the eastern extremity of the Mendip chain, the lias gradually thins off until it becomes evanescent. The strata are remarkably parallel, and, on the small scale, are usually horizontal; but, if we continue to trace them over large tracts of country, we find them to be inclined, and their level to be unequal. Thus at Keynsham, the lowest beds of lias are on a level with the subsided mass of that rock at Bitton, which is nearly that of the sea; whilst at Timbury, 7 miles further to the south, to which place the beds of Keynsham are continued without interruption, they are elevated at least 400 feet higher.

Where the series is fullest, the two upper thirds of the formation exhibit thick beds of dark-blue slaty clay or marl, alternating with a very few thin strata of calcareous marl-stone. Beneath the clay lie the beds of lias, properly so called, which consist of compact limestone, having an earthy aspect, and smooth conchoidal fracture, and these are separated by thin partings of blue slaty clay. The thickness of any one stratum of limestone rarely exceeds a foot, and more commonly falls short of 6 inches, and the frequency of the alternations of these strata with the partings of slaty clay gives a striped and ribband-like appearance to the rock in all its quarries, and fits its stony beds for extensive use as flag-stone. The upper beds of limestone are usually variable in colour, passing from blue to smoke-grey; the lower beds are of a pale yellowish white. The latter, from their even and compact texture, have been recommended for lithographic printing, and specimens applicable to this purpose have been obtained from the neighbourhood of Corston and Bitton. The stony beds of the lias are about 60 feet in thickness, and occupy almost the whole of the remaining third part of the entire formation.

Beneath the limestone beds, a third and lowest division of the formation is sometimes found, which is characterized by the presence of black shale. Between the white lias and the black shale, are strata of dark-grey marl, in some of which occur layers of calcareous concretions, irregularly interspersed. The thickness of this bed of marl usually exceeds 12 feet. It is very variable in its character, being sometimes perfectly stony, and then acquiring a granular and coarsely-oolitic structure. In this state it is known by the name of corn-grit, and approaches in its aspect and colour to the beds of the same name, which belong to the inferior oolite. The subjacent black shale attains occasionally a thickness of from 15 to 20 feet, and contains thin beds of a greenish siliceous grit, highly charged with mica, and loaded with the scales, teeth, palates and bones of fishes, and the bones of many gigantic reptiles. These siliceous strata, from the abundance of their organic remains, are known by the name of "the Bone-beds:" they abound in iron-pyrites, and in rolled fragments of bone and of differently-coloured clay-stone, of which the darker varieties resemble the bone in colour. They probably form an under-bed, coextensive with the lias throughout its whole course in the estuary of the Severn, being found at a spot * on the right bank of that river 7 miles above Gloucester, at the cliff of Westbury a little below Framilode passage, and at the Old Passage in the opposite cliffs of Aust and Annards, in which and in the cliff of Westbury their structure is best displayed. On the right bank they are seen in Monmouthshire at Gold-cliff, and in Glamorganshire at the village of St. Hilary, near Cowbridge; on the left bank on the coast of Somersetshire, at the western extremity of Clevehill, near the town of Watchet †. They are also found at some distance from the Severn, on the

* Mr. Halifax has here procured a black solid bone, larger than the humerus of a horse, belonging to some gigantic reptile.

† This discovery of the bone-bed near Watchet has been made by Robert Anstice, Esq. of Bridgewater. It there forms a stratum from 2 to 9 inches thick, chiefly composed of white quartzose sand, with small pebbles of quartz and a little mica sparingly interspersed, the whole being cemented together by carbonate of lime. The cement occasionally assumes the character of lias, and forms septaria in the bed of sandy breccia. It then is often full of small bivalve shells. The whole abounds with animal remains, which are often inseparably attached to one another by iron-pyrites. The bones are in few cases unbroken, and in one case only has Mr. A. found teeth or palatal bones attached to a jaw or palate, although they all occur abundantly throughout the stratum in a detached state. They are of a jet black colour, and have a highly polished surface; but, from the brittleness of their substance and the hardness of the matrix, it is difficult to disengage without destroying them. Only a few fragments of large bones have been found; the rest seem generally to have belonged to small animals. The remains are as follows.

1. Fragments of spines of the same nature as those represented in plate iv. fig. 1. 2 and 3. vol. i. 2nd series, Geol. Trans. They belong to two varieties; both of which differ in some points from that in the plate referred to, and approach nearer to that described in Walcot's account of the petrifactions near Bath. One of them is less deeply furrowed than that in the figure; the other is scarcely furrowed at all, and has tubercles on the sides towards the point. In neither of them are the dentiform processes so abundant, or so regularly disposed, as in the figure.

2. Many varieties of palates and teeth, some of the latter resembling those represented in fig. 5 to 10 of the plate above referred to.

3. Scales of several varieties of fish, many of them corresponding exactly with those of the

eastern frontier of the Bristol coal-basin, in the road ½ a mile to the east of the town of Wickwar.

All the organic remains, which are commonly found in the lias in other parts of England, occur also in the district here treated of. Near Twiverton and Keynsham have been discovered the Ichthyosaurus and the Plesiosaurus, large compressed fishes, Crustacea of the crab and lobster kind, and the beaks of Sepiæ. Mr. Miller of Bristol has in his collection from the bone-bed at Aust Passage many large tuberculated bodies, extremely compact, and of a jet-black colour, which were probably connected with the palates of some very large cartilaginous fishes. The lias of our district affords all the Testacea most common to the formation, especially Gryphites, the gigantic Plagiostoma, and enormous Ammonites, which at Keynsham have given rise to the same romantic legends respecting the miraculous powers of St. Keyna, as have prevailed concerning St. Hilda at Whitby. Several species of Pentacrinite also occur, one of which found at Pyrton passage and at Frethern cliff is not common.

In tracing the geographical extent of this formation, we find it to the south of the Mendips reposing on the newer red sandstone, which extends beneath the marsh-lands of Somersetshire, the lias probably itself also forming a part of their substratum. Occasionally it emerges above them, and then composes the summit, or, in some cases, the entire mass of several insulated hills, which are sufficiently indicated in the Map [Pl. XXXVIII.], and in the Sections [Pl. XXXII.]. The most remarkable of these is Brent Knoll, which, rising to the height of 470 feet above the sea, and standing quite alone amid the marshes, presents a very conspicuous land-mark.

Towards the eastern extremity of the Mendip chain, and to the south of it, at Pennard and Glastonbury, the lias is but little elevated above the marshes; but, by rising constantly though imperceptibly towards the north, it acquires a considerable height to the north of Shepton Mallet. Here it rises more than

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Dapedium politum, plate vi. fig. 4. Geol. Trans., vol. i. 2nd series; there are also flat bony substances, studded with small tubercles such as belong to the head of that fish.

4. Bones (or fragments of bones) for the most part small, black, and very compact; belonging apparently to some small reptile. Among these only oue vertebra has been found.

There occur also many irregular bodies, varying much in form and substance, which are usually, however, cylindrical with rounded ends, some having a black and glossy surface and fracture, others being of a dull-brown colour. They are probably rolled palates, or rolled fragments of very solid bone.

Fish-bones are here of rare occurrence in comparison of spines, teeth and palates; which circumstance perhaps may be accounted for by reason of the soft and perishable nature of the bone of the cartilaginous fishes, to which the spines, teeth and palates belonged.

half-way up the hangings of the Mendip chain, and overlying all the intermediate formations, abuts against the mountain limestone. The northern and most elevated portion of this inclined plain is traversed by several valleys, which partially exhibit the mountain limestone beneath the lias, in those parallel and broken ranges which have already been described in the 2d chapter. The newer red sandstone and the dolomitic conglomerate may be seen forming upfillings or hanging masses on the rugged surface of these ranges, wherever the mountain limestone does not rise to a level with the plane of the lias. The principal of these valleys is that through which flows the brook that waters Shepton Mallet, remarkable for its cliffs and beautiful scenery.

This valley nearly marks the limits of a very remarkable alteration which the lias undergoes; that portion of it which lies to the north of the valley differing greatly in texture and appearance from lias of the usual character. We here see it in many places serving as a cement to fragments of mountain limestone, and thus passing into a rock which it is often impossible to distinguish from the dolomitic conglomerate. The fragments in this lias-conglomerate are often very large, and sometimes, when they have become decomposed, a singular rock, of a honey-combed appearance, has resulted. From this lias-conglomerate the organic remains of the lias have disappeared altogether. This conglomerate constitutes the eastern part, as far as Birrel farm, of the narrow strip of lias which runs from Crapnel farm near Crosscombe by Chilcot and East Horrington to East Milton near Wokey; in the western part of this strip, from Birrel farm to Milton-house, the lias assumes its ordinary character. As we recede from the extreme boundary of the lias, we find fragments sparingly imbedded in a cement which abounds with organic remains. This variety approaches in character to the usual forms of lias. It is however of a granular texture, which texture distinguishes indeed all the lias to the north of the Shepton valley. In one remarkable variety there is such an admixture of siliceous matter, that the rock, in portions of its mass, becomes a greenish chert.

On the summit of the Mendip hills, to the west of North-hill, near Hydon farm *, we may observe the remarkable appearance of a patch of lias, at a level far above the ordinary level of the plane of the strata of that formation, and at a spot entirely insulated by other and more ancient rocks. It does not attract attention on the surface, nor would its existence have been ascertained but from the sinking into it of a marl-pit, the organic remains from which are decidedly those of lias. Within a furlong, both to the north and south, moun-

* The exact spot nearly coincides in the Ordnance Map with the upper end of the letter I in the word MENDIP.

tain limestone is to be seen *in situ*, which is covered in the immediate neighbourhood by overlying dolomitic conglomerate.

In the valley of the Severn from Tewksbury downwards to Pyrton passage, an extensive and almost continuous sheet of lias reposes on the newer red sandstone, the sinuous course of the river repeatedly crossing their junction, and thus affording numerous sections, of which those of Westbury cliff and the cliffs on either side of Aust passage are the most remarkable.

The most important appearance at Aust is the display of 5 nearly vertical faults, which occur in the face of a cliff not exceeding $\frac{1}{4}$ of a mile in length nor 60 feet in height. The beds exposed in the cliff are three varieties of lias, which repose on two varieties of the marl belonging to the newer red sandstone, viz. the green marl and the red marl. The distinct character and colours which belong to each of these strata, and the clear display of them which is afforded along the whole line of section by the vertical state of the cliff, render this the most eligible spot that we have ever seen for observing the phenomena of faults. The drawings of Pl. XXXVII. will supersede the necessity of a description.

Each of the faults has acted as a dam to the rain-water, which, percolating downwards from the surface, drains over the inclined planes of the strata, and has occasioned the discharge of a spring, which, by covering with a slight stalactitic incrustation the soft materials over which it runs, has protected them from equally rapid destruction with the naked surface of the marl, and given to them a bastion-like projection* beyond the face of the cliff. The waves of the Severn are continually undermining the cliff, and washing out of it large and valuable quantities of gypsum.

Examples of fractured beds of lias, similar to those at Aust, have been already noticed as occurring at Bitton and at other places in the Bristol coal-basin. Another instance may be noticed on the west side of the valley between Keynsham and Compton Dando, where portions of lias are thrown down below an escarpment of red marl; another may be seen on the road-side a little to the south of Cannards grave near Shepton Mallet, and others at Barry island, and thence along the coast of Glamorganshire to Dunraven. Of how rare occurrence are such fractures in strata more recent than the coal-measures in comparison of those which affect the older and inclined beds, may be learnt from the few irregularities of stratification in the lias of Glamorganshire, contrasted with the perpetual disturbances which have heaved the more ancient

* Similar projections are common, under similar circumstances, on the coast of Dorsetshire and Devonshire.

rocks on the coast of South-Wales, westward from Dunraven to its termination in the Atlantic Ocean.

Below Aust the lias is absent for a considerable interval on the right bank of the Severn. It re-appears, however, in one insulated point, remarkable for its contracted dimensions, viz. Gold-cliff, which has before been mentioned, in the centre of the marshes of Caldecot level. Gold-cliff is a hillock not exceeding 50 feet in height, and containing little more than an acre of ground. On its summit once stood an ancient priory. Its face toward the Bristol Channel presents a vertical section about 30 feet high, of which the upper part consists of lias, and the lower of red marl. This section, however, is now almost entirely concealed by a high sea-wall, erected in front of it. The name of Gold-cliff is derived from the iron-pyrites in the lias, as we may collect from the work of Gyraldus Cambrensis, who wrote in the middle of the 12th century*. The occurrence of the lias in the neighbouring parish of Llanwern, and further to the westward in the county of Glamorganshire, has been noticed in the introductory chapter.

On the left bank of the Severn the occurrence of the lias between Henbury and Almonsbury has been before noticed. Between Aust passage and the town of Berkeley it forms insulated caps on the summits of Oldbury, Eastwoods, and White-cliff park; and from Pyrton passage it is continuous in a southern direction nearly in a straight line to Sodbury, occupying the valley intermediate between the calcareous border of the coal-basin and the great escarpment of the oolite. Near Sodbury it touches the outer edge of the low escarpment of old red sandstone and mountain limestone, and commences that protrusion into the interior of the basin, which has already been described in the 2d chapter. Within the coal-area the lias constitutes extensive and somewhat elevated platforms, crowning the acclivities formed by the newer red sandstone, and sometimes supporting higher platforms of oolite. These hills stand completely insulated from one another by numerous intervening valleys, and exhibit on their sides the same series of strata in the planes of those strata prolonged.

Cotham hill near Bristol is an example of one of these hummocks, being

* "Non procul inde stat rupis marina, Sabrinis supereminens fluctibus, quæ Anglorum linguâ *Gould clyffe* vocatur, hoc est *rupis aurea*, eo quod aurei coloris saxa præferat, sole repercussa miro fulgore rutilantia.

Nec mihi de facili fieri persuasio posset
Quod saxis tantum dederit Natura nitorem
Frustra, quodque suo fuerit flos hic sine fructu.

Si foret, &c. . . . . .

crowned with a small cap of lias resting on red marl. It affords beautiful specimens of that irregularly-constructed and knotted form of lias, which is common in cabinets under the name of landscape-marble.

Several immediate contacts of lias with mountain limestone may be noticed in the interior of the basin. Thus at Winford, a long tongue of coarse oolitic lias forms an upfilling in a depression of the limestone of Broadfield-down; and a similar contact may be seen on the inner edge of the calcareous frontier to the south of Westbury and of Almonsbury.

3. Oolite.

It is not our intention to enter into any detail respecting this formation in general, which forms rather the boundary than a constituent part of our district. Its inferior portions will alone require description.

These consist of a coarse oolitic limestone, generally termed the *inferior oolite* or *bastard freestone*, resting on a thick bed of brown ferruginous sand, which often contains irregular beds of calcareo-siliceous concretions, known in Gloucestershire by the name of *sand-bats*. This sand in the lower beds, as it approaches the lias, passes into a greenish-blue marl, and the concretions (which are often very siliceous) are of the same colour; and hence the thin stony and concretional beds in the upper part of the blue lias-marl are often very similar in character to those of the sand in question. They gradually, however, as the series descends, assume the grain and texture of lias.

The preceding is a general description of the lower beds of the oolitic formation, as they exist in the neighbourhood of Bath and throughout the Cotswold hills; and since beds of nearly the same character may be traced southwards to a distance of more than 50 miles, it is presumable that this constitution very generally prevails.

In some points however of our district the sandy beds seem to have given place to beds entirely oolitic. This is especially the case in the lowest beds of this formation, where they rest upon lias to the south of Midsummer Norton, and throughout the plain formed by the same beds near Mells, and thence to the south of the Mendips as far as Shepton Mallet, where they repose immediately on mountain limestone and the coal-measures.

These beds consist of a coarsely-crystalline and loosely-compacted limestone, varying in colour from a straw-yellow to a dull-red, and interspersed with small balls of ochreous rusty powder, produced apparently by the decomposition of ferruginous oolitic grains. In the absence of these grains, the rock becomes a durable freestone, which, as quarried at Dundry, has been used extensively for building in Bristol; that of Doulting, near Shepton Mallet, has been employed for the construction of Wells cathedral, Glastonbury abbey, and most of the churches in that neighbourhood.

The geographical extent of this formation is fully indicated in the Map. Its general boundary is formed by an abrupt escarpment, fronting the north-west, the lower regions of which consist of lias and lias-marl, while the oolite forms the elevated table-land on its summit. After the principal ridges of mountain limestone and old red sandstone, this table-land constitutes the highest ground within our district, attaining near the north-eastern corner of our Map the height of 1000 feet. It is indented near its edges by deep valleys, which often completely surround and insulate extensive portions of it; and even at a considerable distance from the general boundary of the oolite, detached hummocks or outliers of it form abrupt, crested, and conical summits, crowning platforms of lias. Good examples of these outliers are seen in the long ridge of Dundry, which rises 700 feet above the sea, and in the neighbouring hill of Stantonbury of equal height*. For the inferences to be drawn in support of the diluvian theory from the facts here stated respecting the physical structure of the hills of lias and oolite, and of the valleys which intersect them, we refer to the memoir of Mr. Buckland at page 95 of the present volume.

Chapter V.—ON THE DILUVIAL AND ALLUVIAL DEPOSITS.

1. On the diluvial deposits.

The accumulations of diluvial debris in our district are not very striking or extensive. The valley of the Severn seems to have formed their great receptacle, and it is probable also that the extensive marsh-lands to the south of the Mendips conceal deposits of the same kind. The vale of the Avon exhibits beds of gravel on the south of Bath at Bath-hampton and Bath-wick, and to the west of Bath at Twiverton, Newton, Bitton, and Keynsham. Near the mouth of the Avon we find rolled fragments of all the rocks in the vicinity, from the old red sandstone to the chalk, forming considerable heaps, though covered by peat at the surface. These deposits in the vale of the Avon contain the remains of the quadrupeds peculiar to diluvian beds, the bones of the

* Dundry and Stantonbury hills have been chosen, on account of their natural strength, to form part of the ancient fortified boundary of Wansdyke. Their summits have been strengthened by large entrenched camps. This line of entrenchments ranges over Claverton and Farley downs, and is now mentioned only as deriving its strength from the physical characters of the surface. To the south of these hills a group of small similar outliers are scattered over the elevated lias plains on the north of Timsbury, among which the Barrow hills may be distinguished by their singular tricuspidated form.

elephant, horse, and stag, having been found at Shockerwick on the east of Bath, at Newton and at Shirehampton. The tooth of a rhinoceros has also been found in flint gravel on the oolitic summit of Kingsdown near Bath. But still more striking illustrations of the diluvian theory are afforded on the summits of some of the eminences belonging to the Mendips. In several of the hills toward the western extremity of this chain many fissures in the mountain limestone are filled by stalactite mixed with ochre, enveloping and sometimes cementing fragments of the adjacent limestone, and in these masses bones have occasionally been found imbedded. The most remarkable instance of this occurred to the south of Hutton in some pits opened about the middle of the last century by a Mr. Glasson. Their exact locality is immediately above the south-east angle of Hutton wood in the Ordnance Map. They are now partially filled up, but might be re-opened for examination with very little trouble and expense. For the details relating to this fissure, extracted from Mr. Catcott's manuscript, we beg to refer to Mr. Buckland's *Reliquiæ Diluvianæ*, page 57. Ochre is still procured from similar fissures in the limestone at Banwell on the Mendips, and at Congresbury on the south-western extremity of Broadfield down; but we have not yet heard of bones being discovered at either of these places.

Elephants' bones have been found, according to Mr. Catcott, in loose rubble at the depth of 4 fathoms on the summit of Sandford hill to the east of Hutton. Mr. Miller has found those of the horse, encrusted with stalagmite, in a cavity in the mountain limestone near the turnpike on Durdham down.

2. On the alluvial deposits.

The marshes which skirt our district on the south have evidently, at a period comparatively recent, formed estuaries, which have gradually been filled up by sediments of mud from the Severn and other tide rivers flowing into them, and by the growth of Zostera marina and such other plants as concur to produce peat on the sea-coast and in salt marshes. These estuaries have finally been rescued from the sea by artificial embankments, the position of which has often been determined by that of elevated natural banks of muddy sediment, or by the high beaches of shingle which the tides have in many places thrown up. Were these barriers removed, the sea would at spring-tides reclaim its former territory, and, washing the base of Glastonbury hill, show the propriety of its ancient appellation, "the Isle of Avalon."

These estuaries seem originally to have been shallow, the natural sub-soil of lias or red marl, or of the diluvial gravel covering them, being usually found at an inconsiderable depth. On this base reposes a bed of blue clay, being the mud, apparently, which once formed the bottom of the estuaries; and this clay extends beneath the peat, which forms the greater part of the present surface of the marshes.

The silty bottom occasionally passes into sand, which, from its natural tendency to drift, has either been heaped into thick banks in the interior of the marshes, or mixed with shingle has formed lines of beach at the foot of the higher grounds. Such lines of beach may be traced along many parts of the border of King's Sedgemoor, viz. at Sutton, Chedzoy, Weston Zoyland, and Middle Zoy, of which places the three latter retain in the etymology of their names the evidence of their former maritime position. Weston Zoyland and Chedzoy appear to have been low islets in the estuary of the Parret, against which the sand has drifted, and a shingle-beach been thrown up. These banks of sand and beaches of shingle are often protruded through and rise above the level of the peat. We find in them rolled chalk-flints, and fragments of the rocks prevailing in the neighbourhood; so that we have here a confirmation of the opinion previously advanced, that these ancient estuaries have been the receptacles of the diluvian debris of the surrounding district. The clay has not been observed to contain shells; the sand affords them pretty abundantly, identical with the recent English species, and most of them marine, though mixed in some instances with those of the land and fresh water. The marine shells are found at the places just mentioned on the borders of King's Sedgemoor, and in an insulated sand-bank at Burtle, in the marshes of the Brue. In the excavations at Highbridge, near the mouth of the Brue, this shelly sand lay beneath 3 or 4 yards of vegetable soil, and in one place, where buried still deeper, it was covered immediately by a bed of peat 2 feet thick. A similar sand extends beneath the argillaceous silt that forms the surface around Huntspill; it is very thick, and forms a quick-sand full of water. The mixture of land-, fresh-water- and sea-shells above alluded to may be seen at Chilton, one mile below Bridgewater.

The peat which fills these estuaries is in many places 14 or 15 feet thick, and is sometimes separated into two or more strata by partings of clay, each about a foot thick. The common sedge, whence Sedgemoor derives its name, enters largely into the composition of the peat. The peat is very loose in texture, the water with which it is charged in wet seasons raising and (as it were) floating it from off the clay bottom on which, for the most part, it rests; and it is so porous, that some red marl, which Mr. Anstice spread over it, became washed into its substance, and descended in a regular stratum successively to greater depths.

According to the Agricultural survey, trees of great dimensions, both of oak, fir, and willow, have been discovered in these marshes, at the depth of

15 or 20 feet, the roots (according to our own observations) standing in the same upright position in which they grew, but the trunks lying prostrate; and together with them occur furze-bushes and hazle trees with their nuts. Reeds and other palustrine plants appear to have grown among them. Trees have been found buried in peat in the brick-yards at Bridgewater; and in the bed of the river Parret, near its mouth, between Start island and Stone wall, roots and prostrate trunks are seen in peat beneath an accumulation of silt, 14 feet thick. This last mentioned locality is not more than 3 miles distant from the submarine forest at Stolford, described by Mr. Horner, and clearly connects the history of the timber found in the marshes with that occurring on the sea-coast beneath the present level of high-water. Shurton bars, situated about three miles further to the west, and also described by Mr. Horner, exhibits appearances similar to those at Stolford. A similar case, not noticed by Mr. H., occurs on the shore of Blue Anchor bay, between Watchet and Dunster.

The site of the forest of Stolford is at the opening towards the Bristol Channel of a flat marsh, which fills a broad valley. A high shingle-bank, next the sea, preserves the marsh from inundation. The roots of the trees are as thickly placed as in a crowded forest; and the slightest inspection must satisfy any one that the trees grew where they now stand*. The similar forest of Shurton-bars is placed also at the opening of a valley towards the sea; and it appeared to us that the trees grew in this valley at the foot of the neighbouring slope, and that the neighbouring low cliff had been formed by the action of the waves. Neither here nor at Stolford could we discern any appearances which in the least favoured the notion of the ground whereon the trees grew having subsided from a higher level to its present one beneath the waves. These phenomena are identical with those which have been observed elsewhere on the coasts of England, France, the Low Countries, and the North of Germany, where remains of ancient forests are found at a level far below that of the present ocean at high-water.

The peat does not appear over the whole surface of the marshes; but in the more inland parts it is sometimes partially covered by the alluvium of land-floods; and near the mouths of the rivers traversing the marshes, it is concealed by deposits of marine silt, of considerable depth, which often are of extraordinary fertility, producing crops of wheat of 40 bushels per acre for 20 years in succession without manure. Around Huntspill is a tract of this description, partially covered by drift sand. The silt however does not ex-

* These remains of ancient forests are not confined to the low-lands. On the hill above East Harptree is a small peat-bog, in which are found the stems of oak trees in an upright position.

tend far from the mouths of the rivers. Thus in ascending the Brue, its thickness above the peat is seen to diminish, until at length it wholly disappears, and then the peat alone forms the surface to a great distance. On the banks of the river at Bridgewater the peat is covered by 8 or 10 feet of silt; and at Crandon-bridge drain, $2\frac{1}{2}$ miles to the north-east of Bridgewater, by 14 feet of a similar deposit. The stratum of peat is in these instances thin, and apparently compressed. Monsieur de Luc mentions in his geological travels, that in deepening the channel of the river Brue in order to drain Burtle-moor, the workmen, after having dug to the depth of 7 feet in the sediments of the river, found on the surface of the peat which lay beneath, a heap of fragments of Roman pottery, with pieces of the small bricks that are used to separate the vessels in the kiln. Moulds of Roman coins were found on the peat in other spots. Hence it is evident that at the time of the Roman occupation the surface of the peat was exposed, and protected from inundation either by its own natural level or by artificial embankments; but that since that period it has been covered by new sediments to the depth of 7 feet. Mr. Anstice mentioned a similar instance in which fragments of two Roman potteries were discovered at the depth of 12 feet below the silt, 300 yards below Basin bridge. A Roman road crossed the marshes near this point. It is itself constructed on the silt, and is now 6 feet below the level of high-water. These circumstances do not lead to any certain conclusions, as to the former levels of the marshes and the sea, which may have been the same during the Roman occupation as they are at present. The marshes may then have been secured, as they now are, by sea-walls, works of which kind we have historical authority for ascribing to Roman power and ingenuity in many other instances.

Of the various other more recent changes to which the earth's surface is liable, we have only to notice, as occurring within our district, the deposition of tufa from springs charged with calcareous matter. Of this a good example is presented in the Nettlebridge valley, at the north-eastern foot of the Mendip Hills, opposite to Coleford, where, immediately beneath a precipitous bank of mountain limestone, some rugged rocks start through the turf, which prove on examination to consist of an indurated tufaceous marl, containing land shells, and impressions of blades of grass and other vegetables.

APPENDIX I.

On some early Geologists, who have noticed the south-western Coal-district.

We have been induced to throw together a few remarks on some of the early writers in whose works information is contained concerning the south-western coal-district.

The earliest document in which any material information bearing on this subject is to be found, is An Essay on the History of Pembrokeshire, left in manuscript, anno 1570, by George Owen of Henllys in that county, but not published until the year 1796, when it appeared in the Cambrian Register. Copious extracts from this work are given in Fenton's historical tour through Pembrokeshire. This essay of Owen is a work of the highest interest, as being the earliest example, extant in any language, of what can properly be called Geological investigation. About a century before this period, indeed, the attention of several Italian writers had been directed to the organic remains of the Sub-Apennine districts, which there lie scattered in such quantity and preservation as not to have escaped the notice of the poets of classical antiquity. It was the single fact however of the occurrence of marine remains in inland situations that those writers observed; and with the single exception of George Agricola, who about the year 1550, in his treatise de Re Metallicâ, described the more obvious phenomena of metallic veins, no writer until the time of Owen appears to have studied the nature and position of the mineral masses which constitute the crust of the globe.

Owen describes the extent and general features of the mountain-chains of Pembrokeshire, and the course of the rivers to which they give rise, with an accuracy and spirit which it would be difficult to equal. But what chiefly distinguishes his memoir, is the observation, that the mineral masses, constituting the earth's surface, are not thrown together promiscuously, but are arranged in a regular order and in continuous lines over extensive districts; an observation which forms the great basis of all scientific geological investigation. Owen verifies this observation by tracing two bands of limestone, with the beds of coal adjacent to each, along the northern and southern frontiers of the Pembrokeshire coal-field; and that not only through Pembrokeshire, but in continuation through the other counties of South-Wales: that is to say, over a tract exceeding 100 miles in length. He thus anticipates much of the information contained in the valuable memoir on the coal-basin of South-Wales, communicated by Mr. Martin to the Royal Society in 1806.

The connexion of these calcareous bands with those of the Forest of Dean and of the neighbourhood of Bristol is likewise suggested. A third line is also traced to the north of the northern calcareous band in Pembrokeshire, along which Owen supposes another continuous band of limestone to extend. Along this line, however, the calcareous masses which occur, are discontinuous, and are in truth detached portions of transition limestone subordinate to grey-wacké slate, which very generally along that line contains a mixture of calcareous matter.

At the same time that Owen lays down correctly the general fact of the regular arrangement and continuity of mineral masses, he appears to have had confused notions of their position below the surface of the earth. He calls these masses indiscriminately *veins*; is ignorant of the distinction between veins and beds; neglects entirely the dip of the beds, and seems not to have entertained any suspicion that the two bands of limestone, the northern and the southern, had a subterraneous communication, and thus formed a great basin containing the superincumbent coal-measures;—a doctrine afterwards so ably developed in the paper of Mr. Martin. We do not find in Owen's memoir any notice of the organic remains of the several strata.

The Bristol coal-basin has been rendered remarkable by a memoir on its structure by Mr. Strachey, published in the Philosophical Transactions for 1719, which, though later by a century than that of Owen, is yet entitled to very particular mention. This essay was followed by another, containing some supplemental diagrams and observations, published in the Phil. Trans. for 1725. The author gives a clear description of the collieries in the neighbourhood of Brislington and in other parts of the central coal-tract of the Bristol basin; enumerates the seams of coal there worked; traces them to some distance along their line of drift; explains the nature of the faults by which they are deranged; particularly notices the inclined position of the coal-measures, specifying the degree and direction of their dip; and states the important fact, that these inclined strata are partially covered by other strata, which differ from the former in being horizontal:—a distinction not sufficiently kept in view by several distinguished geologists of a more recent date. These horizontal strata are also described as consisting of lias with its accompanying marl, and of red and yellow earth; in which we clearly recognise the lias and newer red sandstone formations. These descriptions are illustrated by engraved sections, which convey an adequate, though somewhat rude, representation of the coal strata, of their faults, and of the overlying horizontal formations. Mr. Strachey has appended to his second paper, diagrams representing the manner in which he conceives the mineral masses to be disposed in the interior of the earth, which, though defaced by the absurd hypothesis of each stratum being continued to the very centre of the globe, yet is important as indicative of his belief in the constancy of the regular arrangement of mineral masses. The following is that arrangement, such as he believed it to exist; and if we apply to it those explanations that his own memoir appears to warrant, we shall find in each of his formations a singularly close approximation to the truth. Of the 12th number of the series, denominated iron, the context does not suggest any obvious interpretation.

Series of Beds in the Order of Superposition, according to Mr. Strachey, 1719.	Interpretation of the Terms used by Mr. Strachey, such as his Memoir appears to warrant.
1. Chalk	Chalk.
2. Freestone	Bath oolite.
3. Lias limestone 4. Marl	Lias formation.
5. Yellow earth 6. Red earth and ochre . .	Newer red sandstone.
7. Coal clives 8. Coal	Coal-measures.
9. Lead	Mountain limestone, containing veins of lead ore.
10. Copper	Slate, containing veins of copper ore.
11. Tin	Granite and other primitive rocks, containing veins of tin.
12. Iron	?

APPENDIX II.

On Red Sandstone.

In the south-western coal-district of England we have three formations of red sandstone, the *newer red sandstone,* the *millstone grit,* and the *old red sandstone,* all liable to be confounded with one another owing to their prevailing red colour, and to their containing beds of conglomerate; and as similar rocks occur, very similarly placed, in various parts of the earth's surface, we find three opinions maintained concerning red sandstone, and each moreover supported by indisputable facts: one, that it lies over the coal-measures; another, that it lies beneath them; and a third, that it is a member of the coal-formation.

The term *old red sandstone* was originally applied by Werner to a formation analogous in character and geological position to our *newer red sandstone.*

Examples of the *rothe todte Liegende,* or old red sandstone of Werner, lying over the coal-measures, may be seen at Norhausen on the borders of the Hartz, and at the Wintberg mountain, a few miles to the south-west of Dresden, on the edge of the Dresden coal-field. It is to this overlying formation of red sandstone that, in our opinion, the associated presence of large masses of salt and gypsum is exclusively confined.

The *old red sandstone* of English geologists, and the mountain limestone which covers it, great as is the thickness and importance of each formation, are not recognised in the classification of rocks which Werner himself has drawn up. An example of both these rocks, identical with their types in England and emerging from beneath the coal-measures, may be seen at Huy in the district of the Meuse, between Namur and Liege.

The *millstone grit* affords the best example in the south-western coal-field of a red sandstone belonging to the coal-measures. But occasionally even in this coal-field, and very frequently in the coal-districts on the continent, all the coal-grits acquire a red colour; and for this reason we now find it to be the prevailing opinion among continental geologists, that the *grès rouge* is a member of the coal-formation.

It is by their relative position to one another as well as to other rocks, that these sandstones are best to be distinguished; but when these points remain obscure, we must have recourse, for the purpose of discrimination, to some of the internal characters detailed in the preceding memoir; such, for instance, as can be observed in the conglomerate beds from the nature of their imbedded fragments, which, should they be indubitable fragments of old red sandstone, mountain limestone, and the coal-measures, would lead us to refer the disputed formation to the newer red sandstone.

The distinguishing characters and relative position of these three formations of red sandstone having been only partially attended to, and much confusion having thence arisen,—in order to remove it, an eminent geologist has proposed the expedient of throwing them all together, and regarding them as belonging to one formation of sandstone, in which are contained subordinate beds of limestone and coal. This view of the subject may appear at first sight to introduce an advantageous simplification; but for the following reasons we cannot consent to adopt it.

With regard to the grits of the coal-measures and of the old red sandstone, since they lie conformably to one another, it may sometimes perhaps be found convenient, in an extended sense, to class them under one formation; and should it happen that both are of a red colour, and (as is the case in Shropshire) that the mountain limestone, which usually divides them, has disappeared, it may then be difficult in fact to distinguish between them. But between both of these and the newer red sandstone there is a complete and total separation. To those rocks the newer red sandstone is unconformable in position, and whenever in contact with them, reposes on their basset edges; it is usually unaffected by the faults and disturbances to which they are subject; it is itself partly made up of the fragments derived from their ruins; and must therefore have been deposited after their consolidation, dislocation, and partial destruction. It is impossible, therefore, to imagine any stronger grounds on which any two series of rocks can be regarded as distinct; and should we agree to throw these together, we might with equal propriety consider all groups of strata, in which beds of limestone occur, as belonging to one great calcareous formation, and treat as subordinate all the rocks that happen to alternate with limestone. But this would be in fact to confound together almost all the rocks with which we are acquainted.

XVI.—*Geological Observations on Part of Gloucestershire and Somersetshire.*

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[Read 4th June, 1819.]

CONTENTS.

Introduction.

§ 1. THE tract included in the view from the northern brow of the hill, on which stands the rectory of Tortworth, is no less calculated to gratify a taste for the picturesque than to excite a lively interest by its geological structure. The rich and beautiful vale of the Severn, diversified by gentle inequalities, is bounded on the east by a bold abrupt escarpment of oolite, from which Stinchcombe-hill projects far out into the vale. In the distance, to the north, appears the Malvern chain of hills, flanked on the west by the Doghill range, and succeeded on the south-west by Mayhill, and the hills which, inclosing the coal-tract of the Forest of Dean, pass on into Monmouthshire. But the more immediate objects presented to the eye from this station, in the vale below, are the narrow transverse valleys of the Avon and Falfield; the former proceeding from the south-east, the latter from the south-west; and coinciding at a short distance above the village of Stone, their united waters pursue a course to the north-west, finding a vent in the Severn below the town of Berkeley. The Falfield valley and the lower part of the Avon are bordered on the west by the isolated table-lands and ridges of Eastwood and Whitecliff park; while the general course of the Avon is bounded on the east by the foot of the great escarpment.

In the view thus described, the eye takes in at a glance a succession of geological formations, extending from syenitic granite up to oolite.

On the other hand, the view from the southern brow, at Wood-end or Lay-hill, bears a different aspect. Here we appear to stand on the northern verge of an elliptic coal-basin, the immediate prospect being confined on either side by a continuous ridge, which, diverging to the south-east and south-west, incloses a plain: eastward of this ridge, the line of the oolite escarpment may be seen extending uninterruptedly from north to south; the horizon being bounded in the latter direction by the Somersetshire ranges, which spread from the great escarpment on the east to the Dundry and Broad-field Down hills on the west, beyond which, in the extreme distance on the south, a part of the Mendip chain appears. The re-entering angle formed by the northern extremity of this basin, bears a close relation to the salient angle produced by the conjunction of the valleys of the Avon and Falfield.

§ 2. To ascertain the nature and connexion of the formations surveyed in these two views, which, taken together, extend between sixty and seventy miles from north to south, is the object proposed in the following pages: and as Tortworth is a position nearly intermediate between the two extremes, and comprehends within a narrow compass almost the whole of the formations that will come under our notice, I shall consider its environs in such detail, as will render unnecessary more than a general view of the north-west of Gloucestershire and north-west of Somersetshire; since in the two latter tracts we commonly meet with only a continuation or repetition of the same formations as occur in the Tortworth district.

§ 3. The immediate environs of Tortworth, which I am about to describe in detail, may be comprised in a triangle, the base of which passes from Oldbury-on-Severn on the west, through Thornbury, Milbury-heath, and Wickwar, to Hawksbury Upton on the east; the two sides converging to a point at

Pyrton on the north; the western side being formed by the left bank of the Severn, and the eastern by a line drawn from Pyrton along the great escarpment of oolite. Of the tract included in this area, I have represented in the annexed map, only so much as, when combined with the sections by which it is accompanied, may be sufficient to convey a clear idea of the relative position and order of succession of the different formations. (See the Map, Plate XXXIX., and Sections No. 1. 2. and 3.; of which the Section No. 2. occupies the whole base line of the triangle*).

The structure of the north-west of Gloucestershire is illustrated by a section drawn from Huntley-hill on the north-east, to the Forest coal-basin on the south-west (see Plate XXXIX., Section No. 4.); and that of the north-west of Somersetshire, by one general section (No. 5.), drawn from the Avon at Bristol on the north, to the river Parret at Bridgewater on the south; and by a second section (No. 6.), traversing Mendip only, in the vicinity of Shipham.

1. ENVIRONS OF TORTWORTH.

General View.—Secondary Formations.

§ 4. One of the first impressions made on the mind, in examining the Tortworth district, is, that the existing form of the surface appears, to a certain extent, to be unconnected with the nature of the rocky formations that compose its base; an observation, indeed, that may admit almost of universal application, and be deemed a maxim in geology. A second impression is, that if the distribution of formations into Primary, Transition, and Flœtz† or sedimentary classes, be well founded,—as resting on distinct epochs in the history and structure of our planet, the evidence of which is to be discovered in their respective characters and relations; it is also true, that natural distinctions point to a subdivision of the sedimentary formations, into collective series or groups, consequent to, and in a great measure independent of each other, with respect to the era of their production. Under this view, the first series of the sedimentary class, namely, the carboniferous, comprehends, in the

* Having no map of Gloucestershire, that conveys an adequate idea of the form of the surface, I constructed the annexed plan and sections of the environs of Tortworth from a survey, in which my pocket-compass and clinometer were the only instruments employed. I trust, however, that they will be found to represent faithfully the form of the country.

† The use of the German term *flœtz* is no doubt so far objectionable, as it does not harmonize with our language: but in its full comprehension the word was intended to convey a complex idea, for the expression of which we have not any corresponding English term, and to denote formations whose leading characters are, a distinctly stratified structure, combined with a

vicinity of Tortworth, the old red sandstone, carboniferous limestone, and coal formation; the second (or gypseous and saliferous series) includes the calcareous conglomerate, magnesian limestone, and new red sandstone; of the third series, which comprises the lias and oolite limestones, the iron and green sandstone, and the chalk, the lias and oolite limestones only appear within this tract: and the fourth and last series, or the formations later than the chalk, are also wanting. The first, or carboniferous series, reposes upon a transition base, while the succeeding formations overlie, unconformably, both the carboniferous group and the transition tract; and this either continuously or in dismembered portions.

§ 5. In the parallel of Wickwar, (Section No. 3.), the elevated ridge of the old red sandstone and its accompanying limestone, the strata of which dip here toward the west, supports, high up on its eastern flank, a deposition of calcareo-magnesian conglomerate, that upholds red clay marl (of the new red sandstone formation) sustaining lias; which last extends to the foot of the oolite escarpment, beyond Ingatestone Common, on the east, a distance of near three miles:—all these beds being arranged in a nearly horizontal position, and forming stages more or less in the form of table lands, with a dip of 2° or 3° towards the east. This part of the course of the western branch of the Avon, is wrought out of the new red clay marl, and the subjacent calcareo-magnesian conglomerate; but in descending to the north, the valley expands

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composition evidently and principally resulting from mechanical agency. I do not however see any material objection to the adoption of the term *sedimentary*, as a substitute for *flœtz*; and hence I shall employ it throughout the remainder of this paper.

That sedimentary deposits occur in transition and primary tracts also, can be no valid objection to the use of the word in this more large and characteristic sense; for these deposits constitute in such cases merely partial and local sub-formations. In the same manner the term *old* red sandstone is not incorrectly applied to the first member of the carboniferous series, although red sandstone occurs also in transition tracts, and, it is affirmed, even in the primary; the latter cases being only exceptions to a general and opposite rule, namely, that a crystalline structure is the more prevalent characteristic; while the red sandstone appears as a consistent and predominant formation, for the first time, and is therefore in a geological sense the oldest, in the first great sedimentary or carboniferous period.

An extended developement of this portion of the text (originally designed as an appendix to the present paper) may be found in the Annals of Philosophy for Oct. Nov. and Dec. 1821; in which I have taken a general, and in part also a detailed view of the flœtz formations, distributed in four principal series; the British members being there also compared with their equivalents on the continent. See likewise on the same subject the Geological Remarks of the author in the Annals of Philosophy, for August 1822 and May 1823.

toward Charfield Green, and the horizontal beds gradually decline from the ridge into the vale, when they become confined to the right bank of the Avon; a zone, however, of the calcareous conglomerate continues to occupy the brow of the sandstone escarpment, passing Charfield Church, and surrounding Tortworth hill, to the north-western extremity of the Park. In this quarter also, detached outlying portions of lias occur, on the brow above Tortworth Copse, and in the dell, which is connected with the north-eastern part of Tortworth Park.

The calcareo-magnesian conglomerate re-appears on the other side of the ridge, in a small patch, within the limits of the basin; and again, on the ridge to the west, in the hollow by which the road passes from the basin to Milbury heath. It forms a zone also around the northern and western escarpment of that heath, and descending into the vale of Thornbury, supports, in conjunction with magnesian limestone, the town of that name; and now occupying a considerable space, extends west, toward the Severn, forming the base of Oldbury hill, and partly also of Aust cliff, and to the north, through Moreton toward Rockhampton. It is succeeded by the new red clay marl, which spreads toward the Severn on the one hand, and on the other, sustaining patches of lias, composes the extended table land of Eastwood, and the upper part of that of Whitecliff Park. In the whole of this expanse of the vale, the disposition of the calcareo-magnesian conglomerate and succeeding formations appears to be nearly horizontal.

The table lands, or stages, of new red clay marl and lias, which border the right bank of the Avon at Charfield Green, and which serve as a pediment to the oolite escarpment, distant about two miles on the east, preserve an easterly dip; extending in their course to the north, past the eastern side of Micklewood Chase, toward the foot of Nibley and Stinchcombe hills; while the red clay-marl alone, occupies the Keeper's ridge situate more to the west. Between the broken escarpments and projecting feet of the two former hills, a kind of amphitheatre is formed, the southern horn of which extends in part toward the Keeper's ridge. Within the circuit of this amphitheatre, the ground is broken into gentle eminences and depressions, exhibiting in the lower parts deep soil, and in the upper, partial deposits of diluvial oolitic debris, which reach down to a line, that we may conceive to be drawn from Woodford Green on the south, past Newport and Breadstone, to Pyrton Passage on the north. The sub-soil, to the east of the former part of this line, appears to consist of new red clay-marl or lias, and in the latter, wholly of lias, which last indeed prevails throughout the vale of the Severn, from Stinchcombe hill on the south, past the city of Gloucester on the north.

The tract included in the area thus described, by following the line of the overlying newer beds, from Wickwar, to Pyrton on the east, and from the western escarpment of Milbury heath, to the vicinity of Berkeley on the west, consists of rocks of the transition and carboniferous series; which are exposed to our observation by the interruption of that continuity, which probably existed between the overlying sedimentary formations on the east and the west, before the general surface of the country was moulded into its present form, by partial abruption and denudation.

§ 6. The general surface of the vales of the Avon and Falfield, is occupied by a considerable depth of highly cultivated soil; but an examination of those valleys, of the escarpments presented toward them and toward the vale of Thornbury, and of the declivities and defiles, which lead from the elliptic ridge into the inclosed basin, has proved that portions of the transition and carboniferous series, together constitute a nearly concentric assemblage of beds; the northern limit of which is to be found near the confluence of the river Avon with the stream of Falfield, and which is thence inflected to the south-east, up the valley of the Avon, and to the south-west up that of Falfield. The dip is conformable to this arrangement, the strata on the north being inclined toward the south, on the south-east toward the south-west and west, and on the south-west toward the south-east; but toward the head of the Falfield valley they are again inflected, gradually acquiring a south-westerly inclination; and in the old red sandstone a north-westerly inclination also, the latter forming in that direction an arched curve, broken at the surface, and therefore in this quarter so far unconformable to the transition tract.

On the other hand, that part of the transition series, which borders the flanks of the concentric assemblage at their northern extremity, pursues a course more directly toward the north, preserving, where visible, a dip toward the west, except at Pyrton Passage, where it appears in the form of an arched inflection.

This portion of the transition tract supports, and is bounded on the west by a second range of the old red sandstone, which extends from the vicinity of Pyrton in a south-west direction to the northern foot of Sunday's hill, in strata variously inclined, and where visible on their eastern boundary, generally unconformable to the transition beds.

Such is the general disposition of the transition and carboniferous series in this district; but they display also occasionally inflections on a much smaller scale, subordinate to and included in the general arrangement, being gently undulated both in the line of range and of dip.

§ 7. Before we enter upon the consideration of the transition and carboniferous series, it may be useful to observe that in both are to be found sandstone, slate-clay, clay, marl, and limestone, the former including also trap. The sandstone and limestone of the transition and carboniferous series frequently resemble each other so nearly as not to be easily distinguished by mere mineralogical character: but their different position in the order of succession, the abundance and variety of peculiar organic remains in the transition sandstone and limestone, and the absence of such remains in the carboniferous series in general, and especially in the old red sandstone, sufficiently distinguish the two series from each other.

1. *Transition Tract**.

§ 8. I propose to trace the transition beds from Pyrton to the vicinity of Stone, and thence to explore the valleys of the Avon and Falfield. But, as a preliminary, let us consider the leading characters of the members composing this transition tract.

The constituents of the transition sandstone are grains of quartz or sand, generally very fine, and sometimes so minute as to be almost imperceptible, among which are scattered minute scales of silvery mica that are often scarcely visible, except when examined by the lens. Particles of felspar are very rarely to be observed. The mass is coloured reddish, or greenish gray, of various shades, both separately and intermingled in a mottled manner, according to the variable state of the oxidation of the iron that enters into the composition, or the proportion of the matter of clay, or slate-clay, that is casually intermixed. Sometimes also the sandstone is coloured greenish by chlorite, diffused through its substance; but in general the reddish hue predominates: while the state of aggregation varies from the most firm to that which is sandy, or earthy, and perishable; the compound, however, being commonly very compact and tenacious. In some cases also the particles are so closely approximated as to constitute a quartzy sandstone, or quartz rock, passing into compact quartz, or hornstone, of a gray or white colour. When adjacent to limestone or slate-clay, the sandstone is frequently intermingled with those minerals, and contains discontinuous layers and portions of them interposed between the strata.

The slate-clay is usually of a reddish, or greenish gray cast, earthy, soft, and perishable; and contains more or less of mica, scales of which appear in

* The term *transition* was well chosen by Werner, as designating a class of rocks the earlier members of which approximate, in mineralogical character, more and more to the primary,—and the later, to the sedimentary formations;—while at the same time, containing the first vestiges of organized bodies, the class comprehends the oldest of the *secondary rocks*.

particular on the planes of separation, (as is also the case with the sandstone,) partially silvering over their surface. When the slate-clay occurs in the vicinity of sandstone, it is often intermingled with sandy particles, and when contiguous to limestone with carbonate of lime; in both of which cases it acquires a firmer consistence and compacter structure. Sometimes also it contains interrupted layers and portions of sandstone and carbonate of lime, parallel to its laminæ.

The structure of the transition limestone varies from the perfectly compact to the foliated granular; and its predominating colour is gray; but it is also casually tinged with red or green, when adjacent to sandstone or slate-clay; and in these cases it is sometimes intermingled with sandy particles, or clayey matter, and envelopes unconnected layers and portions of those substances. It not unfrequently occurs also of a magnesian quality, being then generally of a yellowish or reddish gray cast, and minute foliated granular structure.

These transition beds are often traversed by slight veins and filaments of calcareous spar, and brown-spar; and occasionally also, though much more rarely, are to be observed interrupted layers and veins, and disseminated portions of sulphate of strontian, as well as of sulphate of barytes, all of which bear evidence of a contemporaneous origin.

The sandstone, limestone, and slate-clay, are frequently associated with layers of soft, reddish, blueish, or greenish clay, and also with blueish and greenish white marl, the whole series being found in beds of variable thickness, interstratified with each other. The prevalence of any one member varies in different parts; but in general it may be said that the sandstone predominates in the lower, and the limestone in the upper portions of the series.

The trap is of very variable character in different quarters; consisting of granular and compact greenstone, (the former seldom appearing of a distinctly crystallized structure,) with occasionally disseminated portions of hornblende or augite, sometimes, though very rarely, graduating into basalt; of granular and compact felspar; of clay-stone, and amygdaloid; all of which, being mutually intermixed, frequently interchange characters and pass into each other; and hence the shades of colour are never constant in any considerable portion of the mass, but fluctuate from black, to green, red, brown, and gray, the predominant colours being reddish brown, and gray. The rock sometimes also, though very seldom, assumes a porphyritic appearance, thinly scattered acicular crystals of glassy felspar occurring in its substance. But in general the common aspect of the trap may be said to be that of a compact rather than of a crystalline or even sub-crystalline production; and where steatitic matter prevails, it is of a loose consistence, friable and earthy.

It frequently contains compressed ovoidal and spheroidal nodules and kernels of chlorite, green earth, calcareous spar, brown-spar, and quartz; also balls of calcedony and agate, the internal cavities of which are sometimes lined with crystals of amethyst; and when the more perishable ingredients are removed by decomposition, they leave empty cavities, whence the rock acquires a vesicular and scorious aspect. Sulphate of strontian, sulphate of barytes, and prehnite, appear more rarely in the trap; which sometimes also includes portions approaching to compact brown iron-stone, and brown jasper. Veins, composed of carbonate of lime and brown-spar, either pure, or mixed with trap and chloritic and steatitic laminæ, not unfrequently traverse the rock, occupying the cross fissures, which in some places divide it into cuboidal and other quadrangular concretions. These concretions sometimes exhibit a tendency to exfoliation, disclosing concentric lamellar layers, that surround a spherical nucleus. The structure of the same mass of trap varies much in the course of its extent; it is most frequently amorphous, or irregularly divided by fissures, but when adjacent to the interstratified beds of sandstone, slate-clay, and limestone, a faint tendency toward a corresponding division into strata may be partially observed; while in some other quarters, thin strata, from two to four inches thick, may be casually remarked, singularly contorted and inflected, yet subdivided by cross joints into rhomboidal prismatic concretions. But, in general, the internal structure of the trap may be said to be independent of the interstratified disposition of the beds of which it forms a part: a fact which I have had occasion to notice in other instances likewise, but which does not appear to be peculiar to this rock, since it is also to be observed in other formations, particularly in such as are of a crystalline or of a granular texture *. But even slaty rocks are not free from a similar variety of structure subordinate to their general arrangement †.

Incorporated portions of sandstone, hornstone, and limestone, both common and magnesian, occasionally appear in the trap; and in some places the rock partially assumes the form of a conglomerate, a base of trap enveloping rounded and angular fragments of those substances.

A slight coating of reddish brown oxide of iron is not uncommon on the separating surfaces of the stratified rocks, and particularly on those of the sandstone strata, which may be traced in some cases to a thin pellicle of

* See Geological Transactions, Vol. V. Memoir on the East of Ireland, §§ 61, 69, 71, 79, 172, 175, 176.

† Ibid. § 159. Slate-clay in limestone.—See also the Geology of Derbyshire by Mr. Farey. Vol. I. Article, Limestone shale.

compact brown ironstone or hæmatite. It may appear almost superfluous to remark, that iron enters also largely into the composition of the trap. Generally speaking, when the sandstone, limestone, or slate-clay become partially disintegrated by weathering, they acquire a stained appearance, from the oxidation of the ferruginous particles diffused through their substance; and the same cause produces a similar effect on the trap.

§ 9. The stratified transition beds, now described, abound, in particular parts, in the remains of organized bodies, more especially when they are thinly stratified with each other, or when the sandstone is adjacent to the calcareous beds. But many of the sandstone strata, when nearly continuous, appear mostly, if not entirely, free from them.

The following are the organic remains which I have observed; but many of them are frequently so interwoven and entangled with each other, and with the substance of the including rock, often appearing only as partial impressions or casts, that a reference to distinct species becomes in most cases nearly impracticable. I confine myself therefore, in a great measure, to general indications.

The only remains of *vertebrated animals* that I have met with, are bones and a tooth, apparently of fish; the former in Whitefield quarry and at Skeay's grove, and the latter in Skeay's grove alone *.

Of the *crustaceous* animals, trilobites frequently occur, being referable to four distinct species. Of these, the most common is the Asaphus caudatus of M. Brongniart (*Histoire Naturelle des Trilobites*, Pl. II. fig. 4.); which is also often found in the transition tract of North Gloucestershire, Herefordshire, and Worcestershire. In the Tortworth district, I have never met with a specimen of this trilobite so perfect, as to exhibit at one view the entire form of the animal: but the head, body, and caudal termination of different specimens (though the last is very seldom distinctly displayed), fully establish, when taken together, the identity of the species.

The next species, which is also not of uncommon occurrence, is referable to the Calymene variolaris (Brongniart, Pl. I. fig. 3.); but of this I have never met with a complete specimen. The part most generally exhibited to view is the post-abdomen only; the head is much more rarely visible; and these two parts are found separate and detached from each other, the abdominal portion of the body appearing to be wholly wanting †. The specimens of the head of

* I know of only one other instance in which the remains of fish have been noticed in a transition tract; that, namely, of the impressions in the transition slate of the Blattenberg, near Glarus, in Switzerland.

† The post-abdomen in this species is distinguished by a single row of five small tubercles, of an

the animal that I have met with, agree perfectly with the description given by that author, and a few of them display the oculiform prominence, commonly denominated the eye, in a tolerably distinct manner.

Of the third species of trilobite, which I believe to be a non-descript, I have only found specimens which exhibit separately the right and left lobes of the head; the most perfect of them extending only to the oculiform protuberance, which last is much more elevated than in the two preceding species. Both of the lateral lobes are accompanied by a coriaceous or membranaceous border, which bears a double row of tubercles; each tubercle of the inner, and larger row, being of an oval form and prominent, while the outer tubercles are circular, faintly expressed, and placed close to the edge between the intervals of the larger. Each of the lateral lobes or cheeks, which supports the high oculiform projection (and between which and the coriaceous border is a longitudinal depression), is also provided with a double row of tubercles nearly equal in size to each other, and placed below the eye parallel to the external border. From the general disposition of the parts, it is probable that the membranaceous border is continued around the central lobe of the head also; but I have never succeeded in developing a complete head, the materials being very fragile: nor have I observed any other portion of a trilobite that might be thought to appertain to this species.

The fourth and last species of trilobite is the *Calymene of Blumenbach* (Brongniart, Pl. I. fig. 1.), of which, however, I can merely record two specimens, each presenting only a considerable portion of the head, which I found in Long's quarry, adjacent to Charfield-green. In the same quarry, which yields some of the most distinct organic remains that occur in the Tortworth district, are to be met with also the other trilobites just described *.

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hemispherical form, placed in the middle of the central lobe; each tubercle being opposite to the alternate transverse folds or articulations of the lateral lobes. The articulations of the central lobe are merely marginal, being in number to those of the lateral lobes as three to two; two of the former corresponding with the latter, and the third being placed opposite to the interval between the folds of the lateral lobes. Each of the latter articulations is also generally provided with an ill-defined tubercle adjacent to the central lobe. I thought the preceding description might be useful, as the figure given by M. Brongniart but faintly expresses this part of the subject.

* The trilobites most commonly found at Dudley, are the Calymene of Blumenbach, and the Asaphus caudatus; the Calymene variolaris appearing to occur there very seldom. But the Calymene macrophthalma (Brongniart, Pl. I. fig. 5.), for which the only locality given by that author is Colebrookdale, is met with also at Dudley, though rarely, and likewise at Lincoln's hill in Shropshire; having been found in both those localities by my friend the Rev. Dr. Cooke, Rector of Tortworth.

Of *chambered univalves* we meet with orthoceratites, the Conularia of Mr. Miller, and one species of ammonite. Of the last, however, there has occurred only one incomplete specimen, which was found by Dr. Cooke in a detached state near Falfield quarry. Orthoceratites are not uncommon, affording three or four, if not five, species, smooth and annular, obtuse and conical or pyramidal, with the chambers generally disposed at right angles to the siphuncle; but in one species they form an oblique angle. The orthoceratites are in general ill displayed; among them, however, may be observed Orthocera circularis (Sowerby, Pl. LX. fig. 6 and 7.) and Orthocera annulata (Ibid. Pl. CXXXIII.). I found only one small specimen of Conularia quadrisulcata, (Ibid. Pl. CCLX. fig. 3 and 4.); in Whitefield quarry.

Of *univalves not chambered,* there occur occasionally euomphalites (namely, Euomphalus discors, E. angulosus (Sowerby, Pl. LII. fig. 1 and 3.) *; nerites, helicites, melanites, turbinites, and dentalites; patellites, if such they be, very rarely. Of these last I can record only a few specimens, one of which, found in Whitefield quarry, has some resemblance to the Patellites primigenus of the Baron Von Schlotheim, which occurs in the transition limestone of the Duchy of Berg (*Nachträge zur Petrefactenkunde,* Pl. XII. fig. 1. b.); but as my specimen is merely an impression, it may possibly be only a cast representing in relief the concave surface of one of the vertebræ of a fish; the fish bones above noticed also occurring in the same bed. A second specimen found at Pyrton, and two others at Long's quarry, are widely different; none of these, however, are sufficiently distinct to enable me to speak with decision on the subject †.

The dentalites appear to be of two species; one annulated, the other resembling in form the tubes of a telescope drawn out at short distances; but both terminate conically. They are similar to those organic remains found in the transition rocks of the Continent, which have been described by some writers as Tubulites geniculatus and as orthoceratites, and latterly, by Baron Von Schlotheim, as Tentaculites annulatus, and T. scalaris (*Petrefactenkunde* Pl. XXIX. fig. 8. a. b. and fig. 9. b.). But Mr. Miller informs me that on rubbing down two diluvial boulders of transition limestone, containing similar remains, met with near Dantzig, he found them destitute of chambers, and consisting merely of hollow slender cones, externally annulated. Yet, if the

* The Euomphalus rugosus also, depicted in fig. 2. of the same plate, is found in the transition tract of the north-west of the county, particularly at Longhope.

† It appears, however, that patellites occur in the transition tract of Wales, having been noticed by Dr. Gilby junr. in his valuable account of a part of that tract, extending from Breconshire into Radnorshire. (*Edinb. Philos. Journal*, Vol. II.)

specimen be rubbed down only to the smooth part of the shell, a deceptive appearance sometimes arises, from the annuli near the pointed extremity, showing divisions like septa: these, however, vanish on continuing the abrasion into the interior of the cone. Mr. Miller considers them as forming a new genus, following the imperforate dentalia comprised in the genus Cæcum.

Of *bivalves* we meet with various species of anomites, terebratulites, spiriferites, and productites, some of the species agreeing with remains found in the carboniferous limestone, while others are wholly different; also casts resembling mytilites, including several species depicted by Baron Von Schlotheim (*Nachträge zur Petrefactenkunde*), as derived from the transition limestone of the Continent, and principally from that of the Hartz, the Eiffelgebirge, the Duchy of Berg, and from Gothland: e. g. Terebratulités priscus, T. striatulus, T. lacunosus, T. elongatus, T. intermedius (a spirifer). Those casts also, derived from terebratulæ and anomiæ, and known by the name of *hysterolites*, are common. Some of them agree closely with those found by Messrs. William Phillips and S. Woods near Snowdon, fig. 4, 5, 6, and 10. of the Plate annexed to the paper of those gentlemen on the geology of Snowdon and its vicinity *.

The *coralloid* remains are numerous, being referable to the genera Caryophillia, Turbinolia, Favosites, Astrea, Madrepora, Cellepora, Millepora, Flustra, Retepora, and Tubipora. Of the Tubipora catenulata, however, which appears in some measure characteristic of the later portion of the transition series, and which occurs not unfrequently in the north-west of Gloucestershire and in Herefordshire, only one specimen has been met with, which was found by the Rev. Mr. Halifax, Vicar of Standish, adjacent to the Horsley trap quarry.

Crinoidal remains also are not uncommon, derived principally from cyathocrinites, but apparently also in part from actinocrinites.

Of the organic remains, now enumerated, the sandstone sometimes retains only the empty impression; more frequently it exhibits them as casts, composed of sandstone, hornstone, carbonate of lime (the latter not unfrequently possessing the nacreous lustre), brown-spar, oxide of iron, the substance of slate clay, and even, though more rarely, of sulphate of strontian. These casts represent either the general form, or the external or internal surface merely. In the limestone, they sometimes consist of calcareous spar, more rarely of brown-spar; in the slate clay of carbonate of lime, or oxide of iron; and in the marly clay of carbonate of lime. These remains, however, as before stated,

* *Annals of Philosophy*, Dec. 1822.

are often very obscure, being implicated with each other in the substance of the rock.

In many parts of this district also, may be observed numerous straight and curvilinear protuberances, disposed either singly, or in an interlaced manner, on the separating surfaces of the beds of sandstone and slate clay. They are indistinct, but seem partly referable to coralloid remains.

§ 10. At Pyrton, on the Severn, the relations of the rocks are disclosed by the operations of the tide. To the south of the Passage-house, the transition beds, among which are some partly composed of magnesian limestone, appear on the strand for a short distance, thinly interstratified with each other, and disposed in a gently arched form, the strata dipping beyond the crown of the arch 20° to the north-east and south-west. In the former direction, they underlie the lias limestone formation, and their actual contact may be seen at low water, at the landing place immediately under the Passage-house; the lias preserving a conformable dip, and extending thence up the river. In the south-west direction, diluvium and alluvial soil occupy the coast for some distance, beyond which the old red sandstone, to which we shall return in a future part of this paper, appears in a conformable position.

The transition beds re-appear to the east of Pyrton, and again at Wanswell, and on the right bank of the Avon, extending toward Stone through Oakley farm to Ponting's quarry, the sandstone generally predominating. At the last-mentioned place the beds dip 32° to the west, 18° south; but on the banks of the Avon at Stone they dip 20° toward the west; and the same westerly inclination is observable throughout the eminence which supports that village; beyond which, near the Eastwood stream, the sandstone reposes on the transition beds in an unconformable position, dipping towards the east.

In the transition tract on the right bank of the Avon, opposite to Stone, trap makes its appearance in two old quarries, situated on the north and south of the Gloucester road; but the fallen state of these quarries prevents further observation.

§ 11. In a country deeply clothed with soil, it is generally by a combination of detached observations alone that we can arrive at a just conclusion. Hence I have been careful in noting the relative position of all the transition rocks, wherever they have been exposed by natural or artificial causes, whether consisting of trap or stratified beds. Of the latter, sandstone generally prevails on the right bank of the Avon. At Woodford-green, and the two by-roads leading to the Middle Mill, the stratified beds dip generally 15° to 25° toward the west: they flank the Woodford trap, forming on the westernside an intermediate body, by which the Woodford trap is separated from that of Horsley. But on the eastern side, the strata are disposed, for a short space near the great quarry, in such a manner as may have led to the opinion, that the trap of this vicinity forms dykes intersecting the other rocks. At the spot here referred to, the trap and stratified beds are seen in close contact, and, at the point of junction, in a nearly vertical position; but in receding from the trap the strata become inflected in the form of inverted arches, dipping near the trap toward the east, and on the opposite side of the curve toward the west, at first at high angles, but at length the low westerly dip becomes general. The breadth of the inflection does not exceed five or six feet, and appears to be so superficial, that little doubt can remain that the eastern body of strata underlie both the inflection and the trap itself. An observation to be made hereafter will tend to confirm this view of the subject. The Horsley trap has been stated to contain organic remains, first noticed, I believe, by Mr. Shrapnell junr. of Buteley. The Rev. Dr. Cooke informs me, that on opening the upper part of the quarry, adjacent to the sandstone strata, a bed about ten inches thick, containing corallites, was met with, situated close to the extreme side of the trap. The bed, therefore, seems to have been incumbent upon, rather than included in, the trap.

On the other side of the Avon, to the west of Middle Mill, trap also appears, and may be traced for about one hundred yards; and beyond it on the west the stratified beds occur; but the depth of soil opposes further research.

§ 12. The transition beds, which flank the Woodford trap on the east, may be traced from the Gloucester road along the base of the Keeper's ridge to Micklewood Chase. The surface of the Chase appears as a table-land, inclined 3° toward the east, being occupied in that direction by deep diluvial clay; but toward the west and north the rocks are more lightly covered. Along the northern brow of the Chase, a fence is drawn to the west, in constructing which the surface of the rocks has been cut into. Measuring along this line, and the quarries contiguous to it, from east to west we find, (see the Map,)

1. Trap .	70 fath. wide.	Quarried 90 fathoms in a north and south direction.
1. Stratified beds	75 . .	Also partly disclosed by a small trench.
2. Trap . . .	60 . .	Quarried also in part toward the south-east, while a second quarry appears in that direction, which is opened 90 fathoms toward the north-east and south-west.
2. Stratified beds	60.	

3. Trap .	75 fath. wide.	Opened also by a small quarry on the south-east; and again by a second more to the south-east, 50 fathoms to the north and south; while at a considerable distance, on the same range, may be observed superficial openings upon the trap; to which the most south-eastern quarry appears to belong.
3. Stratified beds . .		extending to the brow of the valley. They may be traced along the brow, and down the declivity to the two cottages on the west, and thence to the southward partly, on the eastern flank of the 4th trap, and in spots between the 3d and 4th trap.
4. Trap .	70	This appears close by the river on the right bank, extending up the brow above the southern cottage, and ranging continuously to the trap quarries situated north and east of Damory bridge. The quarries in the line of range on the south-east appear also to belong to it.
4. Stratified beds . .		occupying the salient angle on the right bank, and reposing on the 4th trap as a base. On the southern side, the river is again in contact with the trap, beyond which the stratified beds line the right bank of the river, to the brook that flows into the Avon, below the new red clay marl escarpment on the east.

The stratified beds, wherever exposed on the right bank, dip generally, in the lower part of the valley, at an angle of 30° to 35° to the south, 30° west; and in the upper part 15° to 25° to the south, 20° west. This disposition was also clearly shown to exist near Damory quarry, in a portion of the stratified beds No. 4.; and similar beds are partially exposed on the north-eastern side, in which quarter may also be observed large masses of sandstone and slaty sandstone, enveloped in the substance of the trap, and disposed conformably to the general arrangement, the dip being south-westerly.

These observations tend to justify the conclusion, that in Micklewood the stratified transition rocks include four great beds of trap; and if we make allowances for undulations and inequalities in the respective masses, and may presume that they are continuous, it seems probable that

No. 1, trap of Micklewood, corresponds to that of Woodford-green.

2. . . . . to that of Horsley and the trap adjoining the Lower Mill.

3. . . . . to that situate west of Middle Mill; but

No. 4. trap is not traceable, in the valley to the north, beyond the spot where it appears by the river side.

Before I leave the right bank of the Avon, I must notice an inflection which occurs in the stratified beds near the southern cottage above the Iron mill, and apparently in the vicinity of the north-eastern side of the 4th trap, yet not in contact with it. The beds are here exposed, for a space of about 12 feet in length and 5 feet in breadth, and form an arched curve, broken off on the south-west, but inclined on the north-eastern side of the arch at an angle of 35°. Here then is a convex inflection, while that observed on the eastern side of the Woodford trap was concave (§ 11.). But these appearances, arising from subordinate undulations on the small scale, are not confined to the vicinity of trap; and in the brow to the north, the beds observe the general dip, south 30° west, at an angle of 36°.

§ 13. The mutual relations of the stratified transition beds and the trap may be distinctly traced also at Charfield-green, on the left bank of the Avon. They form there a gentle eminence, in which alone they can be examined; for toward the north-east and south, the overlying new red marl and lias formations, and the diluvial depositions, prevent further research.

This eminence is occupied,

1. By stratified beds, from the bridge to the eastern trap, being	110	fathoms wide.
2. Eastern trap	40	
3. Stratified beds	200	
4. Western trap	40	

and then stratified beds again, extending toward the escarpment on the west.

That the trap is here interposed in beds parallel to the stratified rocks, is shown by the fact that, in all cases admitting of observation, the latter are found dipping 20° to 32° to the west, 10° south, close to the eastern sides of the two bodies of trap; while on their western sides they preserve the same dip. These stratified beds consist of sandstone, in beds varying from 2 or 3 to 6 or 8 inches in thickness, and alternating with layers of reddish and greenish clay, blueish and greenish white marl, and thin beds of limestone; the sandstone predominating. They are well exposed in Long's quarry; where sulphate of strontian frequently occurs, in the form of thin interrupted veins and layers, or in disseminated portions.

Beds of this description may be seen in the most southern quarry, reposing conformably on the western side of the eastern trap; and again, in the most northern quarry, called Cullimore's, on the western side of the western trap, dipping 25° toward the west. The lowest bed in the latter quarry, reposing upon the trap, is a conglomerate, composed of small fragments and rounded portions of limestone, slate clay, and sandstone, with some trap-like matter cemented by carbonate of lime; above which the substances next in succession consist of thin beds of marly clay and sandstone in alternation, containing numerous organic remains. These appearances, which occur near the middle of the western side of the quarry, are in the north-western portion attended by other circumstances (see Plate XXXIX. fig. 2.). Here, beneath the grass land and loose soil, appear,

1. The stratified beds just described, exposed to about four feet indepth; partly in a loose state, from disintegration.

2. Mass of trap, three feet thick.

3. A layer composed of sandstone, slate clay, carbonate of lime, oxide of iron, and trap-like matter, intermixed, from four to six inches thick: this being connected with the beds No. 1, the mass of trap No. 2. appears to be inclosed between them.

4. Trap, four feet thick.

5. A layer, analogous to No. 3., but terminating in a fissure towards the south.

6. Continuous trap.

The layers No. 3. and 5. contain numerous remains of caryophyllites, favosites, astreites, bivalves, &c., and I found also the impression of a trilobite. These layers are connected on the north with irregular fissures, which, passing through the trap, converge, and terminate below. The fissures are occupied chiefly by a conglomerate, compounded of trap, limestone and sandstone, in which the trap predominates, containing organic remains, assembled, as it were, in clusters. But in the continuous trap No. 6. no organic remains are perceptible *.

* One of the lowest of the stratified beds (described above under No. 1.) consists of gray hornstone, containing, like the rest of the beds, organic substances; and a similar bed appears adjacent to the trap at Horsley quarry (§ 11.). An advocate for the igneous origin of trap might possibly from these circumstances infer, that sandstone has been here consolidated and converted

Nearer toward the escarpment on the west, the stratified beds contain continuous limestone some fathoms in thickness; and thin beds of magnesian limestone also appear.

§ 14. Descending by the left bank of the Avon, no continuous rock becomes visible until we reach the trap of Avening green; from whence, flanked on both sides by the stratified beds, it may be followed with little interruption to Daniel's wood on the north-west, in which quarter it partly consists of amorphous basalt; its average breadth appearing to be about 40 fathoms. On the north-eastern side the trap is evidently superior to the stratified beds, which may be traversed uninterruptedly from Damory bridge up to the trap, dipping at an angle of 20° to the south, 30° west.

If, pursuing the relations of this body of trap, we descend from the top of Daniel's wood to Cinderford bridge, we observe,

1. Trap; then a little below.
2. Sandstone, 10 or 15 fathoms wide, indistinctly displayed: this contains calcareous casts of shells.
3. Trap, a considerable way down the hill.
4. Sandstone, sometimes approaching to hornstone, with some limestone, the whole apparently two or three fathoms wide.

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into hornstone, by the heat which emanated from the trap when in a state of fusion. But in the present case it may be objected to this view of the subject: 1. That both the hornstone and trap are in immediate association and contact with beds of soft clay, marly clay, and granular sandstone; while on the other hand beds of hornstone are found throughout the stratified series, and in some instances far removed from the vicinity of trap. 2. The organic remains contained in the layers and fissures connected with the upper surface of the bed of trap, seem to prove that in this instance the deposition of the latter preceded the former. 3. Viewing the regular arrangement which prevails in general throughout the transition formations of this district, both in range and dip, it is evident that the trap constitutes discontinuous beds included in and parallel to the continuous series of the stratified transition beds; much in the same manner in which discontinuous beds of other rocks appear in other formations; as of quartz-rock in clay-slate, of limestone in transition clay-slate, of gypsum in magnesian limestone, of rock-salt in new red sandstone. If any one of these be of simultaneous origin with the formation in which it is inclosed, it may fairly be inferred that the others are so likewise: and these formations being undeniably aqueous products, I do not perceive how we can avoid extending the same origin to trap also when found under similar circumstances; a view that is confirmed by the latter containing contemporaneous veins of calcareous spar and brown-spar, similar to those which occur in the contiguous transition sandstone and limestone. And the same may be said of all the formations of trap that constitute portions of particular series in the primary and older secondary epochs, in which I can perceive no proof of an origin posterior to that of the series of which they respectively form a part.

5. Trap, about one fourth of the thickness of No. 1.

6. Limestone, sandstone, and slate clay, in alternating beds, the first predominating, and the whole forming a body about 200 yards in width. These beds dip to the south at angles varying from 25° to 60°, but are inflected towards the Avon and Falfield valleys, dipping in the former to the west of south, and in the latter to the east of south.

7. From hence to Cinderford bridge, a distance of about 300 yards, the sandstone and slate-clay principally appear, dipping toward the south.

Trap becomes again visible on the south-west, and may be followed for some space in Daniel's wood, where it probably ceases, as the stratified transition beds may be traced almost continuously across the vale of Falfield up the escarpment of Tortworth hill, nearly to their junction with the old red sandstone.

§ 15. The left bank of the stream of Falfield is marked by a curvilinear ridge of transition trap, which extends from Skeay's grove past Falfield and Whitefield, to the head of the valley, being there joined by the north-western projection of the old red sandstone of Milbury heath, thus closing and separating this vale from that of Thornbury. In the transition series west of the ridge near Falfield, beds of sandstone predominate, dipping at an high angle toward the south-east; but nearer toward Sunday's hill, they approach the vertical position, and then incline at a considerable angle toward the north-west. The transition beds therefore appear to constitute in this quarter an arched inflection, broken at the surface.

In the brow of the ridge near Falfield itself, the limestone beds prevail, and apparently also in the greater part of the vale; e. g. in the small eminence situated between Falfield bridge and the north-western extremity of Tortworth Park, where they dip generally toward the south-east, at an angle of 40°: but in Barber's quarry they are partially inflected, dipping to the east 15° north; the upper strata there consisting, to the depth of ten feet, of common limestone, and the lower of loosely coherent masses, partly composed of sandy magnesian limestone, with cavities lined by crystals of calcareous spar, and connected by marly clay.

In Skeay's Grove, the beds dip 20° to the east, 25° south; in Falfield quarries, from 42° to 55° to the south-east, being gently undulated both in the line of range and dip. In the north-eastern quarry, they succeed each other thus:—

1. At top, limestone with some slate-clay .	3 feet thick.
2. Marly slate clay, with interrupted layers of limestone	5

3. Firm bed of limestone, with interrupted layers of sandstone, from 2 to 4 inches thick, closely incorporated with and adherent to the limestone,	12 feet thick.		
4. Bed of slate-clay and sandstone	0	6 inches.	
5. Sandstone and limestone intermixed	1	6	
6. Bed of slate-clay and sandstone	0	6	

7. Sandstone, in strata disclosed for a few feet in depth, each stratum being from one to two feet thick. Below these, thin beds of limestone again appear, in the quarry adjacent on the west.

The marly bed No. 2. is in particular rich in coralloid remains. In one part, the beds are traversed by a slight vein of sulphate of barytes, bearing compact brown ironstone.

Following the ridge to the south-west, transition limestone prevails, dipping to the south-east, and higher up the valley, to the south-west, being curved in that direction. In Whitefield quarry the beds, which dip 12° to the west 30° south, are composed as follows:

1. At top, sandy slate-clay, and sandstone, with some limestone, and marly clay, in beds a few inches thick, including in the lower part a layer of sulphate of strontian, in detached portions, three or four inches thick.

2. Beds of limestone, four and five feet thick, alternating with beds of quartzy sandstone one foot thick, and containing also thin streaks of the same substance, all firmly adherent to each other. The sandstone is sometimes much charged with chlorite.

3. Beds of limestone, interstratified with thin layers of slate clay; sometimes also enveloping rounded and angular portions of the latter, so as to form a kind of conglomerate.

4. Strata of clayey sandstone, slightly exposed.

It was in the beds No. 3. that I found the fish bones already mentioned (page 326) the patellite, and conularia; and here also Dr. Cooke met with a small insulated portion of slaggy mineral pitch.

Similar beds appear to succeed each other, almost uninterruptedly, from hence to the stream on the south-west; beyond which, ascending Milbury escarpment, transition limestone is exposed in continuous strata 10 or 12 fathoms in thickness, followed higher up by thinner beds, in alternation with slate-clay and sandstone;—all dipping into the hill, and there supporting the old red sandstone.

II. FLŒTZ OR SEDIMENTARY TRACTS.

a. *First sedimentary or carboniferous Series.*

§ 16. In this series are comprised, the old red sandstone, the mountain or carboniferous limestone, and the coal formation.

§ 17. It has been already stated generally (§ 6.) that the old red sandstone appears in this district in two distinct ranges, a northern and a southern; these however may not improbably have been originally only one, subsequently broken up and dissevered.

The northern range, commencing at its southern extremity, at the northern foot of Sunday's hill, extends along the eastern foot of Whitecliff Park ridge and the left bank of the Avon below its junction with the Eastwood stream, toward the town of Berkeley, which is seated on this formation, and thence to Sharpness Point, on the left bank of the Severn, and up the river nearly to Pyrton Passage; being bounded throughout on the east by the transition tract, already described, on which it reposes. At its northern extremity, on the confines of the transition beds near Pyrton (§ 10.) it appears in a conformable position, dipping to the south-west, preserving this arrangement to Sharpness Point, where it gradually becomes horizontal, and then rises up, inclining at an angle of 6° to the north-east; and beyond that point an extensive flat of alluvial land lines the shore. The gently waved disposition of the old red sandstone on the right bank of the river, corresponds with that on the left bank, but is still more continuously obvious, the formation being there partly of greater elevation; and the same rock extends without interruption from Nass Point on the south, (where it has again acquired a south-westerly inclination,) to Gatcombe cliff on the north,—in which quarter the strata are inflected in the form of a perfect arch, probably derived from a corresponding arch of transition beds beneath, this spot being directly opposite to the transition arch at Pyrton on the left bank of the river: on the right bank, however, transition beds are not visible. We have already seen, that at Pyrton the transition series supports, in the north-eastern direction, the lias limestone formation (§ 10.); but on the opposite coast at Gatcombe cliff this formation reposes on the north-eastern plane of the old red sandstone, being there also in a conformable position. More inland, on that side of the river, the old red sandstone gradually acquires a high angle of elevation, supporting, in its circuitous range around the Forest of Dean, the carboniferous limestone, which two rocks, with the intervention of a bed of sandstone and sandstone conglomerate, conjointly inclose the coal-basin of the Forest.

The strata of the old red sandstone, which thus line both banks of the

Severn, correspond so perfectly in position and structure, that no doubt can exist of their original connexion. The colour of these banks is very striking even at the distance of several miles, appearing of a dark reddish brown, or brownish red hue. Let us now consider their constitution.

The formation exhibits considerable variety of character, consisting of beds of stone, slate, clay, and marl, which frequently alternate with each other, the clay and marl predominating. The ingredients composing these beds, may be generally said to consist of grains of quartz,—red, iron shot, indurated sandy clay, and clay marl,—with numerous scales of silvery mica; from the different size and intermixture of which substances arise the higher or lower state of compactness and induration, and power of resisting disintegration, observable in the different beds. The sandstone varies from the small to the minute grained, in which the particles are scarcely recognisable by the eye. Occasionally also, yellowish, opake, grains of felspar, sometimes passing into the state of earthy felspar or white clay, are intermingled in the compound. When the scales of mica become profuse, and are disposed in a parallel direction, a slaty micaceous sandstone is formed. The clay beds consist of a predominance of indurated clay commingled with fine sand and dusty particles of mica, the whole forming a tenacious compound, but which also frequently acquires a slaty structure. The clay marl differs from the clay, only in containing a proportion of carbonate of lime diffused through its substance; and some of the lower beds (which are probably not far removed from the subjacent transition tract) acquire a conglomerated structure, as at Sharpness Point and in the Wheel Rock on the opposite shore, the base of clay marl enveloping numerous small, irregularly angular and rounded portions of sandy micaceous limestone, which, being less destructible than the clay marl, project above the wasted surface of the latter *. The marly and clayey beds appear to diminish in number and frequency, as we ascend in the series toward the Forest coal-basin, the sandstone almost exclusively prevailing. This fact may be distinctly observed by following the defiles, that lead up from Blakeney and Sidney respectively into that coal-field, traversing in their course the stratification of the country.

The old red sandstone of the banks of the Severn, though in general of a

* At the foot of the cliff on the south-western side of Sharpness Point, I found a piece of the sandstone which contains a few fractured remains, apparently referable to dentalia; much resembling in form Dentalium elephantinum, with the exception of being imperforate. They may have been originally derived perhaps from transition beds beneath; but I have no where observed this species of dentalium in the transition tract itself. In no other part of this range of old red sandstone, have I perceived any vestige of organized bodies.

red colour, appears also occasionally of greenish and grayish hues, the same mass of stone not unfrequently displaying them all together, separately or intermingled. On the other hand, the clayey and marly beds in particular abound with green and blue streaks, which intersect the strata in all directions; and irregular patches, spots, spheroidal and ovoidal nodules, possessing similar colours, are scattered through them; while in the cliffs may sometimes be observed circular and oval rings of blue and green, as if laid on with a painter's brush, being in fact so many sections of nodules possessing a different central colour. These delineations and differences of colour, appear to be owing in part to the variable state of oxidation of the iron, that enters into the composition of the rock.

This range of old red sandstone is also partially exposed in other quarters, e. g. at the town of Berkeley, in the Eastwood stream west of Stone, at Lobden quarry, and in various places extending toward the foot of Whitecliff, Park ridge, and of Sunday's hill; generally reposing in its eastern confines unconformably on the transition tract.

§ 18. The southern range of old red sandstone may be traced, in conjunction with the carboniferous limestone, continuously through the elliptic ridge from Chipping Sodbury on the south-east, past Wickwar, to Tortworth hill their extreme point on the north, where the former obtains a thickness of about 120 feet; thence descending to the south-west into the vale of Falfield, rising again in Milbury heath, and proceeding thus along the interrupted ridge that extends past Tytherington and Alveston to the Bristol Avon, west of Clifton, being partially overlayed in its course by the newer sedimentary formations. This elliptic ridge dips throughout towards the coal-basin. It has been already remarked, however, (§ 6.) that the old red sandstone forms in the northern part of Milbury heath an arched inflection, rising from the south-east and inclining to the north-west: but along the western brow of that heath, the sandstone is so much abrupted that the south-eastern inclination alone is visible. More south, in the projecting range that extends westward towards the Severn, between Alveston and Thornbury, the arch appears to be again complete, the sandstone supporting the limestone in a conformable position, dipping to the north-west. It appears also, that such has been the general arrangement in the line of prolongation toward the Bristol Avon on the south-west; though the beds are greatly abrupted in their course and partially concealed from notice: and a similar disposition is also observable in these two formations in the vicinity of Pen Pole, not far from the estuary of that river.

§ 19. Confining our attention to the elliptic ridge with its inclosed basin, in the immediate environs of Tortworth, we find the sandstone alternating with limestone, and the two supporting the coal formation ; but the immediate base of this last formation consists of a broad belt of sandstone and sandstone conglomerate.

What may be termed the fundamental portion of the old red sandstone, is best displayed in Milbury heath and Tortworth hill. In general character it accords with the sandstone of the banks of the Severn ; but in the higher beds, yellowish and grayish strata prevail, sometimes containing interstices filled with iron ochre ; while clayey or marly beds are comparatively rare, and of smaller dimensions. In some of the upper strata may occasionally be observed a laminated structure, the laminæ forming oblique angles with the planes of stratification, a disposition that has been sometimes also remarked in other rocks. On the other hand, in the lower portion of the formation, there occurs a considerable body of sandstone conglomerate, which may be traced from the north-western foot of Milbury heath to Highwood in the vale of Falfield, and thence around the northern foot of Tortworth hill nearly to Tortworth church. The conglomerate consists of rounded and angular fragments, some being as large as turkey's eggs, of yellowish, whitish, and reddish quartz, with smaller pieces of slate, compacted by a base of granular quartz, —in which are scattered some portions of indurated clay, and particles of felspar mostly in a decayed or earthy state, and also a few scales of mica. The base of the conglomerate is partly of a grayish, partly of a reddish cast ; the rock is commonly disposed in beds, varying from 2 feet to 6 feet in thickness, divided by other beds of firm fine grained sandstone, or red perishable micaceous sandstone, two feet thick ; which last contain thin layers of conglomerate.

Pursuing the curved line, formed by the course of the old red sandstone, from the head of the Falfield valley to the vicinity of Wickwar, we find the strata inclined

At the north-western foot of Milbury heath, .	45° to the N.W.	
At the northern brow of ditto, . . .	10° W. 30° S.	
At the south-eastern side of ditto, where the sandstone supports the limestone in a conformable position, ...	20° S. 20° E.	
In the vale of Falfield and north-western part of Tortworth park and hill, ...	30° S. 40° E.	
In the north-eastern brow of Tortworth hill		
the lower beds, ...	20°	S. 35° W
the upper beds, ...	10°	

In the eastern brow of ditto, facing Charfield green, ...	25° W.
In the ridge at Wickwar, ...	30° W. 5° N.

I have no where observed any vestige of organic remains in this sandstone, except in its north-western extension from Milbury heath to a place called the Nap, on the road toward Thornbury, distant about a quarter of a mile from the Bristol road; where I found it containing a few impressions, resembling the stems, or stalks and branches, of plants *. The sandstone here preserves the north-westerly dip. About a quarter of a mile further to the west, it is overlaid by the calcareo-magnesian conglomerate.

§ 20. The limestone also is inclined at various angles in different parts of its course. Thus the strata are found inclining,—

In the northern portion of the field ;—		
adjacent to the sandstone, ...	10°	to the S. 25° W.
upper part of Layhill, nearly horizontal ; and then, ...	12°	
Layhill quarry †, ...	16°	
In the eastern portion of the field ;—		
In the eastern quarries, west quarter, .	13°	S. 30° W.
east quarter, .	13°	W. 30° S.
In the ridge extending to Wickwar, gradually increasing from, . . .	15° to 35°	more and more toward the W.
In the western portion of the field ;—		
At the northern end of the lake in Tortworth park,—and thence, . .	30°	to the S. 35° E.
In the ridge on the west of the lake, .		S. 25° E.
Extending toward Stanley's wood, .		S. 20° E.
In Stanley's and Prest's woods, . .	40°	S. 20° E.
Through John's wood, ...	60°	S. 30° E.
In the Tytherington ridge ‡, . .	57°	S. 25° E.
But where in immediate contact with the old red sandstone of Milbury heath, high up on its eastern flank, the dip is only .	10° to 15°	S. 20° E.

* An analogous occurrence has been noticed by Dr. Bright in the old red sandstone near Bristol. Geol. Trans. vol. iv. p. 201.

† The strata are here from 2 to 4 feet thick, intersected by slight rectilinear cross fissures; one set of fissures ranging east 35° south, and dipping 82° toward the north-east, the other ranging north 35° east, and dipping 80° toward the north-west. Hence the strata have a tendency to divide into rhomboidal masses: a structure not uncommon in continuous limestone, as well as in many other rocks, and which has often led to the confounding of seams of division with those of stratification.

‡ In the prolongation of this body of limestone to the south-west, the same disposition may be

§ 21. In the northern portion of the field, the limestone is uninterrupted by other beds; but on approaching the plain it alternates with sandstone, of which the first bed that appears is forty fathoms in thickness. I have traced it around the basin, from West-End near Wickwar on the east, into the Tytherington ridge on the west; and in the whole of this course its position is conformable to that of the limestone in which it is included. The same may be said of two or three other beds of sandstone, from 1 to 2½ feet thick, which succeed the bed last mentioned, and are interstratified with the limestone. These may be followed from the Tytherington ridge into the dell north of Cromhall church; and analogous beds are occasionally exposed to observation on the eastern side of the basin. These beds of sandstone are generally of a grayish or yellowish white colour, seldom tinged with red, and are composed of granular quartz, with incidental scales of mica, and, rarely also, grains of felspar.

§ 22. The carboniferous limestone of this district is in general of a blueish gray colour, of various degrees of intensity, sometimes verging toward black; occasionally also, when adjacent to sandstone, of a reddish hue. Its structure is commonly compact, also conjointly compact and foliated, very rarely granularly foliated. It is not unfrequently fetid. When contiguous to sandstone, a reciprocal incorporation often ensues, the latter being penetrated with carbonate of lime, and the former with sandy particles. This is particularly observable in the vicinity of the forty fathom bed of sandstone, where the limestone, on either side, is, in the first place, intermixed with visible grains of sand; but at some distance from the line of contact, the limestone, both above and below the sandstone, acquires the oolitic structure, which it retains throughout the range from Tytherington to Wickwar. It would seem as if the proximate cause of this disposition were minute particles of sand; a progression being traceable from the granular sandy, to the perfect oolite limestone. The upper and lower beds of this description do not appear to possess a determinate thickness; the inferior strata sometimes consisting of nests, or clusters, of oolite limestone, enveloped in the compact. The oolitic structure is most distinct in the eastern quarter, but in the northern and western portions of the range, the grains are in general so minute, that the stone at first sight appears to be compact. The continuous limestone is, not unfrequently,

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observed on the banks of the Bristol Avon, where the limestone strata dip in general to the south 20° east, at angles varying from 20° to 40°. In this limestone, a bed of bituminous coaly shale, varying from a few inches to one foot in thickness, has been lately discovered near the Hot Wells.

traversed by small contemporaneous veins and strings of calcareous spar, which mostly range in the line of the dip; while some may be observed proceeding from a common trunk, ramifying upwards into filaments, and finally closing and disappearing in the solid limestone above; much in the same manner as granite veins are sometimes found to arise from a body of granite and to penetrate into superincumbent slate. I noticed this fact in particular, in the limestone quarry of the cliff situate in the dell beyond the southern extremity of Tortworth Park.

In the Tortworth district, many of the strata of the carboniferous limestone appear to be destitute of organic substances; but in some these form particular assemblages, in others they are thinly scattered. I have observed the following: of *univalves not chambered,* Cirrus acutus, and a depressed species of Cirrus, with circular whorls, approaching in form to that of an Euomphalus; a species of Helix, a Melania, and a Turbo; of *bivalves,* anomites, terebratulites, spiriferites, and productites; of *echinites,* the spines only; of *crinoidea,* such remains as are chiefly referable to actinocrinites; and of the *coralloid* order, caryophyllites, madreporites, tubiporites, and reteporites.

I have also remarked, on the separating surfaces of the small sandstone beds, impressions and casts of caryophyllites, terebratulites, and entrochites, both in the Tytherington ridge, and on the opposite side of the basin; and again, with vegetable remains also, on the northern side of the sandstone ridge on which stands the church of Cromhall.

§ 23. The limestone with the included beds of sandstone, now described, is succeeded by a broad belt of sandstone, which dips,

in the northern part of the field	10° to 16°	to the S. 35° W.
the north-eastern . .	28° 31°	. W. 30° S.
the north-western . .	30° .	. S. 20° E.

This belt contains limestone and sandstone conglomerate, in beds apparently incidental, since their continuity is not traceable to the east and west; and on the other hand, the limestone which occurs south of Cromhall church, seems to be, in a manner, interlocked with sandstone.

This broad belt of sandstone and conglomerate, immediately surrounding the coal-field, agrees in many of its characters with the fundamental old red sandstone and conglomerate. It is however, free from clayey or marly beds, and varies from the state of a fine and minute-granular rock to that of compact quartzy sandstone, or hornstone. In a small superficial quarry, opened to the east of Cromhall Rectory, it exhibits relations that deserve attention, the following beds appearing:—

1. At top,—strata of sandstone conglomerate.
2. A bed of limestone, 2 to 3 feet in thickness.
3. Fine-grained reddish sandstone.
4. Thin beds of quartzy sandstone, with slight layers of slaty sandstone.

The limestone No. 2. contains numerous entrochites, and also some turbinites. The subjacent red sandstone No. 3. is, in the line of contact, firmly adherent to and incorporated with the limestone, and contains casts of terebratulites and entrochites, composed of calcareous spar; but at a greater depth, the carbonate of lime disappears, and there is left a porous, easily frangible sandstone, bearing the impressions of those remains. The quartzy sandstone beneath, No. 4, exhibits casts and straight and curvilinear protuberances, apparently referable to coralloid or vegetable remains; and also casts and impressions of Cacti, analogous to those described by Martin in the *Petrificata Derbiensia.* The Rev. Mr. Woollcombe, in excavating for his cellar at the Rectory, found in the sandstone impressions of caryophyllites, of productilites, and other bivalves.

From this spot, the sandstone extends uninterruptedly to a dell or hollow, that borders on the coal-field, and which seems, in a manner, to form its natural boundary. On the south side of the dell, the sandstone, which thus immediately underlies the coal-field, dips in the northern quarter 16° toward the west of south, and in the western quarter 20° to the south, 20° east, being gently undulated both in the line of range and dip. It is composed of white or gray fine-granular quartz, with a few minute scales of silvery mica, and contains in some places compact brown ironstone, and hæmatite, in slight interrupted layers, or in disseminated portions; and it is traversed by slight fissures, the surfaces of which are coated with oxide of iron of a deep red colour. Impressions and casts of stems and branches of plants are not unfrequent in this sandstone.

§ 24. The coal formation near Cromhall, forms the northern extremity of an extensive coal tract, which passing to the south toward the Bristol Avon diverges thence into the vales of Somersetshire. Of the coal tracts of Gloucestershire and Somersetshire, we are promised a detailed account from the joint researches of Professor Buckland and the Rev. W. D. Conybeare; and the subject being in such able hands, I shall confine myself to such notices as are immediately connected with the lines of section which I have given, of certain portions of those tracts.

The Cromhall coal-field has been partially explored on its northern and north-western edge, by means of pits and shallow levels connected with the dell mentioned in the last section. But the principal work was established about forty-five years ago, in the northern portion of the field, about 500 yards south of the dell, where an engine shaft and a bye pit were sunk about eighty yards in depth, while shallower pits were also opened further to the north in the field. These workings were soon abandoned; and no written document remains, explanatory of the beds that were passed through. The rubbish of the old pits and shallow levels, exhibits fine close-grained sandstone, reddish and grayish slate-clay, some clay ironstone, bituminous shale, gray indurated clay, and compact quartzy sandstone with flakes of black shale.

Within the last few years, the working of this same colliery was resumed; a steam engine having been erected on the old engine shaft, and new pits opened in the northern and north-western portions of the field; but after three years work, the undertaking has been again relinquished. I am indebted to Mr. Walker, the lessee of the colliery, for the following account of the disposition of the beds in this field, taken in one of the basset pits, where they appeared most regular:

	Yds.	Feet	In.
1. Soil and clay	2	0	0
2. Gritstone, or sandstone	25	0	0
3. "Clunchy bind," or indurated slaty clay	1	0	0
4. *Coal*, bituminous, very tender, yielding only small coal	0	2	3
5. "Stony clunch," sandy indurated clay	2	0	0
6. "Rock," sandstone, partly compact and quartzy	15	0	0
7. "Duns," slate clay	2	2	3
8. "Black duns," bituminous shale, being the immediate roof, very tender	0	0	9
9. *Coal*, bituminous, yielding large coal 16 inches, small coal 14 do.	0	2	6
	49	1	9
10. The "floor;" consisting of "clunch more or less stony," that is, of indurated clay more or less sandy.			

The dip of the beds, where they preserved an uniform plane in the field, was generally one in three, or 20° toward the west of south; but this seldom continued to any great extent, as they were more frequently undulated, forming troughs and saddles.

The coal varied extremely in thickness in different places; having been found in some parts thirty inches, in others fourteen inches, in others again six inches thick, while in some quarters no coal at all was to be seen. It never retained a regular thickness for many yards together; and, in some places (rather contrary to the general rule) it diminished gradually in the line of the dip, until it disappeared altogether.

The faults observed here were innumerable: principally ranging north and south, and producing a down-throw from east to west, which varied from two or three yards to twenty yards. These faults occurred at various distances, from ten to fifteen yards, and thence to one hundred yards asunder. They were all composed of the debris of beds of the coal formation, and one, two, three, and four yards in thickness; but one fault was cut through which was thirty-five yards thick. These were accompanied by smaller fissures, diverging, or "flying" from the principal one, and likewise interrupting the strata, though to a less extent; so that the whole of this northern extremity of the coal-field was in a fractured and dislocated state.

To the preceding statement I have to add, that in the slate-clay were occasionally found thin discontinuous layers of clay-ironstone, which also sometimes appeared in the form of spheroidal and ovoidal nodules and masses; both the slate-clay and clay-ironstone exhibiting reed-like impressions and casts. And in the slate-clay over the lower coal seam, I observed an interrupted layer of sulphate of strontian, from one to two inches thick.

In a pit lately sunk near the north-eastern edge of the field, a bed of conglomerate was met with, composed of rounded and angular fragments of slate-clay and quartz compacted by slate-clay. This seems to be the lowest bed of the coal formation, reposing on the fine-grained sandstone of the dell.

The remains of the stems and branches of plants that occasionally appear in the broad belt of sandstone, may be referred in general to the variolariæ of Sternberg; and those of the shale and clay-ironstone of this northern extremity of the coal-field, to the calamites and syringodendra of the same author. I have not observed any felicites, or other leafy impressions, in the shale or ironstone.

In the north-western quarter of the field, an alluvial formation of bog iron ore occurs, occupying a small space, in a superficial position *.

b. *The second sedimentary,* or *gypseous and saliferous Series.*

§ 25. The rocks of this series, including the calcareous conglomerate, magnesian limestone, and new red sandstone and clay-marl formations, do not any where appear in great force within this district; and they constitute but an inconsiderable body, when compared with the same formations in other

* Since the preceding account was written the working of the Cromhall quarry has been again partially resumed.

parts of the kingdom. Their general position and extent, in relation to the tract under consideration, as well as those of the succeeding lias and oolitic limestone, have been already described in § 4. and § 5., and in part also illustrated by the map and sections 1. 2. and 3, Plate XXXIX.

§ 26. The characters of the calcareous conglomerate have been so fully given by Mr. Horner (Geol. Trans. Vol. III.)*, and by Dr. Bright, Mr. Warburton, and Dr. Gilby (Geol. Trans. Vol. IV.); that a short description of the formation, as appearing in this district, will suffice. It is composed principally of rounded and angular fragments of limestone and sandstone, sometimes exceeding the size of the head, with fragments also of hornstone and quartz: these are cemented by a calcareous paste, which is frequently of a marly nature, or a common carbonate of lime either of an earthy or compact structure; but in some quarters, as in the vale of Thornbury, the cement is generally magnesian, and through all the varieties, sandy particles are more or less distributed. The compound abounds in cavities which are frequently lined with crystals of calcareous spar and quartz, and sometimes also with sulphate of strontian. The formation, where it is in contact with older rocks, is generally disposed conformably to the declivity presented by their surface; but the higher strata soon acquire an horizontal arrangement. It thus extends from the western escarpment of Milbury heath into the vale of Thornbury; and in the latter quarter, it is well exposed in a small precipice on the south-western side of Thornbury castle and church, which edifices are founded on the conglomerate. The upper part of the rock is rubbly, the lower part perfectly consolidated, in nearly horizontal strata, about four feet thick. In the vale of Thornbury, this conglomerate in some portions passes into magnesian limestone, the general character of which is that of a fine and minute foliated granular rock, of various shades of gray, yellow, and red. In the limestone-fragments of the conglomerate, entrochites, terebratulites, and productites, sometimes appear; those fragments being evidently derived from the carboniferous limestone. To the east of Wickwar, on the other hand, the conglomerate supports a yellow, earthy, magnesian limestone, the upper part of which alternates with the red clay-marl of the new red sandstone formation, in layers two or three inches thick.

In the conglomerate on the northern brow of Tortworth hill, besides the

* In the part of England, which is considered in Mr. Horner's valuable paper, the magnesian limestone formation seems to be wholly wanting; and hence the calcareous conglomerate of that tract is not unfrequently in contact with the new red sandstone formation, forming its immediate support.

usual ingredients, I have found also pieces of oolitic limestone, the origin of which is evident from what has been already mentioned (§ 22.) respecting the oolitic character of the carboniferous limestone in certain places.

§ 27. The general characters of the new red sandstone in England, may be collected from the instructive papers of Dr. Holland, Mr. Horner, Mr. Winch, and Professor Buckland, in the 1st, 2d and 4th volumes of the Geological Transactions. Wherever this formation appears in the Tortworth district, it is commonly in the form only of red indurated clay or clay-marl, seldom acquiring the firm consistency of sandstone. In composition and general character it agrees so strikingly with the clay and clay-marl of the old red sandstone formation, that the description which has already been given of the latter may in a great measure be applied to it. The tenacity of the compound in both, is various; arising from the different intermixture of ferruginous matter with clay, marly clay, minute sand, and glimmering particles of mica; and the same delineations of blueish and greenish colours occur in it, traversing the reddish brown or brownish red ground, in the form of streaks in all directions, or appearing as the sections of spheroidal and ovoidal nodules. The distribution of mica, however, seems less profuse in the new, than in the old, red clay-marl. The state of aggregation also is in general less firm in the former, which is seldom wholly free from calcareous matter, and commonly effervesces more or less with acids, though often very weakly: the newer marl on the other hand, sometimes appears as a simple indurated clay with a conchoidal fracture. In this vicinity, the new red clay-marl is best exposed at the western foot of the eastward ridge, on the road from Falfield to Rockhampton, where it occurs in horizontal strata.

Masses of sulphate of strontian are frequently to be met with in this formation, e. g. near Wickwar, Charfield-green, and the northern brow of Tortworth hill, where a small patch of the new red clay-marl covers the zone of calcareous conglomerate that surrounds that hill. They are found also in the Keeper's ridge; and Dr. Cooke informs me, that in sinking a well in that ridge a bed of fine white granularly-foliated gypsum was discovered *.

* The general distribution of the sulphate of strontian in this part of the kingdom is remarkable. In the preceding pages, I have more than once adverted to its appearance in the transition beds. Near Bristol it has been found in the carboniferous limestone. Near Cromhall I observed it in the slate-clay of the coal formation. Its occurrence in the calcareous conglomerate, magnesian limestone, and new red clay-marl, of Gloucestershire and Somersetshire, is not at all uncommon; and in the lias limestone it is found in Aust cliff, and also near Watchet on the Somersetshire coast: (Geol. Trans. Vol. IV. p. 371). In the whole succession of formations, therefore, from the transition beds up to the lias limestone, it appears to be wanting in the old red sandstone only.

I have no where perceived any vestige of organized bodies in the new red sandstone formation.

c. *Third sedimentary Series.*

§ 28. Of this series, in which are comprehended the formations of lias and oolite limestone, of iron and green sandstone, and of chalk, the first two only are found in this district; consisting of beds of compact, sandy and oolitic limestone, in association with beds of clay, marl, and sand; the compact argillaceous limestone bearing, as is well known, the name of *lias*.

§ 29. The general characters and relations of the lias limestone, as exhibited in the south-western part of Somersetshire, and in the north-east of Ireland, have been described in the very valuable papers on those tracts respectively, by Mr. Horner, and by the Rev. W. D. Conybeare and Professor Buckland, in the third volume of the Geological Transactions *. Its relations may also be studied to advantage, somewhat beyond the limits of the district included in the map (Plate XXXIX.) at Pyrton, and at Ingatestone Common, on the road between Wickwar and Hawkesbury Upton. Its relative position at those places, with respect to other formations, has been already noticed (§ 6. and § 10.). At Ingatestone Common, the lias limestone is interstratified with blueish clay-marl and slaty-clay-marl, which are exposed to the depth of twenty or thirty feet, in the brook near the boundary of the parishes of Wickwar and Hawkesbury. The upper beds, in which those of the clay-marl predominate, abound in ammonites, ostracites, gryphites, pectinites, &c.; while in the deepest bed of limestone here visible, which is about one foot thick and reposes on blue clay-marl, some fish bones may be occasionally observed. The limestone is much intermixed with hornstone and flinty matter. Nearer towards Wickwar, the lowest bed of the lias formation is found resting on the new red clay-marl; and it there contains numerous fragments of bones, forming a kind of conglomerate analogous to the osseous bed that occurs in the lower part of the lias, in Westbury and Aust cliffs on the banks of the Severn.

At Pyrton, on the left bank of the Severn, where the lower beds of the lias formation appear, the limestone greatly predominates, alternating with thin beds of blue clay and clay-marl, and extending some distance up the river; but still further upward the latter beds prevail. Near Pyrton, I observed the following organic remains: of *chambered univalves*, ammonites, nautilites, belemnites; of *univalves not chambered*, trochites; of *bivalves*

* The lias of England in general has been described, more fully, by the Rev. W. D. Conybeare, in the Outlines of the Geology of England and Wales, 1822.

terebratulites, Spirifer Walcotti (*Sowerby*), ostracites, gryphites, pectinites, pinnites, modiolites, tellinites, venulites, plagiostomites, a species of Astarte, Hippopodium ponderosum (*Sowerby*); of *echinites*, the spines and fragments of the body; and of the *crinoidal family*, pentacrinites. Stems and branches of wood likewise occur, both half decayed and in the state of coal, firmly encased in the solid lias limestone. In the collection of Dr. Cooke are vertebræ, bones, and palates of fish, and radii of balistæ; also crustacea bearing some resemblance to prawns and shrimps;—most of them obtained from the ossiferous beds of the lias formation at Westbury and Aust cliffs,—in which also occur, adjacent to the new red clay marl, bones and vertebræ of the plesiosaurus; while at Pyrton, the remains of the ichthyosaurus are found in the blue marl and clay above the lias limestone. Several of the above-mentioned organic remains are met with also in the lias of Eastwood and Whitecliff-park ridges, in that adjacent to the right bank of the Avon, and in the outlying portions of lias at Tortworth.

§ 30. I am not aware that a continuous section from the lias to the oolitic beds is any where distinctly displayed within this district; and the portion of the oolitic series which appears in the great escarpment, that bounds the vale of the Severn on the east, belongs to that division which has been distinguished as the lower oolite by Professor Buckland, and by Messrs. Conybeare and Phillips. The following appears to be the general arrangement of the beds in the environs of Tortworth:—

At bottom,

1. The lias limestone.
2. Lias clay and marl.

Above these,

3. Brown marl alternating with beds of marly sandstone.
4. Ferruginous sand, containing balls of sandstone, composed of concentric layers, surrounding calcareous nuclei. In the upper strata of this bed, thin layers of oolite occur.
5. Inferior oolite; traversed by fissures of variable width, the walls of which are frequently coated with rock-milk (Chaux carbonatée spongieuse of *Hauy*), or with stalactite. The lower strata of this oolite often contain small tubular or cylindrical channels, closed at both extremities.

The preceding beds constitute what may be termed the exterior terraces of the escarpment, and are succeeded higher up in the interior by the Fuller's earth and great oolite.

An outlier of the bed No. 3. occurs also in the southern end of Whitecliff-park ridge, on the top of the hill, above Hill court, appearing there as a thin stratum of friable, yellowish brown, marly sandstone, surmounting the lias in a nearly horizontal position. It consists of minute grains of quartz with scales of silvery mica, connected by a calcareous medium, and contains indistinct impressions of small bivalves.

With respect to the organic remains contained in the marly, sandy, and oolitic beds, included under the name of the Lower Oolite, I confine myself to the general notice of such as I myself have had an opportunity of observing, or such as I know to have been taken from thence; referring to the collection of the Rev. Dr. Cooke, in which most of the following may be found; of *fish,* palates and teeth; of *chambered univalves,* ammonites, nautilites, belemnites*; of *univalves not chambered,* trochites, melanites, turbinites, volutites, serpulites, patellites; of *bivalves,* trigonites, Lutraria gibbosa (*Sowerby*), astartites, venulites, myacites, modiolites, pinnites, terebratulites, ostracites, pectinites, solenites, cucullæites, and arcacites; of *echinites,* both the body and spines; of the *crinoidea,* pentacrinites, and the Apiocrinites rotundus; and of the *coralloid tribe,* caryophyllites and astreites. Pieces of fossil wood also occur, partly in the state of coal.

To this list I have to add remains of the Plesiosaurus, found in No. 3. of the beds enumerated above, in Newend quarry, at the foot of Stinchcombe hill; some blocks of that stone, in the collections of Dr. Jenner and Mr. Shrapnell jun. of Berkeley, containing vertebræ, portions of the spine, ribs, and other bones apparently belonging to that animal.

II. NORTH-WEST OF GLOUCESTERSHIRE.

General Relations.

§ 31. Beyond the Severn, in the north-west of Gloucestershire, the transition tract re-appears on an enlarged scale, affording a fuller insight into its general structure. It forms a continuous range, which, commencing near Flaxley on the south, passes by Longhope, includes Huntley hill in Gloucestershire, and May hill in Herefordshire, and thence extending further into the latter county and skirting the north-eastern foot of Perrystone hill (from the summit of which we command one of the finest panoramic views any where to be seen), takes its course to the west of north past Marcle hill to Stoke Edith, and expands in the western quarter to Townhope on the Wye. This

* In the *Annals of Philosophy* for Dec. 1821, I have stated that orthoceratites also occur in the lower oolite. I have since found the information upon which that statement rested to be incorrect.

range is flanked throughout on the western side by the old red sandstone, and apparently by the same formation on the north-eastern side also, in the space that intervenes between Much Marcle and Ledbury; while on the north the old red sandstone likewise appears, surrounding the isolated transition hill of Shucknell. But in the eastern quarter, between the north-eastern foot of May hill and Newent, a small coal-field reposes on the transition tract. On the other hand, to the east of Ledbury we encounter a second range of the transition series, bearing the name of the Doghill chain, whose general course is also toward the north, and which is supported on the east by the chain of Malvern.

On the south and east of the limits now described, the new red sandstone formation universally prevails, commencing on the right bank of the Severn, near Newnham, and consisting of beds of red friable sandstone and clay-marl; this supports lias limestone on its eastern confines, and is thence expanded into the interior of the island.

§ *32.* Of the Malvern range, and the district adjacent to it, the valuable description given by Mr. Horner in the first volume of the Geological Transactions, may seem to render further observation superfluous. Hence I confine myself to the remark, that the chain of Malvern—being found to consist of syenitic granite, syenite, greenstone, and hornblende, with some indications of gneiss and mica-slate, in which no organic remains have been observed, might be held to be of primary origin; if on the other hand the occasional appearance in those rocks of calcareous spar, brown-spar, and sulphate of barytes, both traversing them in the form of small veins and strings, and occurring also disseminated, did not seem to indicate an affinity between this chain and the transition series;—since the latter, by which the chain is bounded on the west, likewise contain slight veins and filaments, and interspersed portions, of the same substances. (See Geol. Trans. vol. i. p. 289—311.)

In the Doghill range, immediately to the east of Ledbury, and in the interrupted ridges situate more eastward, the transition beds are disposed in repeated undulations from east to west; the ridges themselves affecting a northerly and southerly extension, nearly parallel to the range of Malvern. But portions of these ridges being also occasionally raised into protuberant knolls and swells, the beds are found in some places dipping to all points of the compass, either continuously, or partially abrupted.

§ *33.* I have not had an opportunity of fully developing the stratified structure of May hill, and its southern extension to Huntley hill and Nott's hill: It is, however, quite analogous to that of the other portions of the transition tract, in which the strata are more distinctly exposed. In the ridge to the north, between Perrystone hill and Much Marcle, the strata appear disposed in the form of an arch ; and this arrangement is traceable further south : but no where in this range is the variation in the position of the strata so well observable, as in the line of the public road leading from Huntley to Mitchel Dean. The repeated undulations of the transition beds, more or less abrupted at the surface, may there be traced, in continuation, from the western flank of Huntley hill, nearly to their junction with the old red sandstone. I have represented this disposition of the strata in Section 4.*

§ 34. If we advert to the general characters of the series, we find them in most respects corresponding with those described in the Tortworth district. The chief difference consists in the frequent occurrence in May hill, Huntley hill, and Nott's hill, of beds of red conglomerate and coarse sandstone, with sandstone of finer grain passing into granular quartz or quartz rock,—in no wise different, as far as respects mineralogical character, from many varieties of the first or old red conglomerate and sandstone of the sedimentary class; but the former are distinguished by the occasional appearance of such organic remains as distinctly prove them to belong to the transition period, e. g. near the summit and in the flanks of May hill †.

The sandstone predominates to the western flank of Huntley hill, beyond which blueish gray limestone, marly slate-clay, and marly clay, prevail; in these, however, beds of magnesian limestone, and thin beds of fine-grained sandstone, may be occasionally observed.

In some quarters also, the limestone beds acquire the conglomerated aspect, nodules of limestone being enveloped and cemented by a clayey or marly paste, more or less firmly consolidated, as near Ledbury. These marly shales and clays are provincially known by the names of *waterstone* and *die-earth*.

* May hill, according to the Ordnance Survey, is 965 feet above the level of the sea.

† The prevailing constituents of these conglomerates and coarser sandstones, are, rounded and angular grains of quartz (some being as large as nuts), with rounded and angular fragments of reddish and yellowish decomposed slate, and grains of felspar of the same colours, in a partial state of disintegration, passing into white earth. Quartz is the more common connecting medium of the whole, but occasionally the cement is argillaceous; while the interstices that sometimes occur are partially filled with yellow or red oxide of iron. The same composition may be traced from the coarse red conglomerate to the finest grained sandstone, until the particles become almost imperceptible to the eye. Very fine grained grayish white sandstone also occurs, consisting of grains of pellucid quartz, more or less approximated, with minute grains of felspar interspersed, and sometimes connected by a basis of crystalline carbonate of lime. And, while the reddish hue predominates, the series in general may be said to exhibit the same varieties of colour,

In the ranges of the transition beds, now noticed, the same organic remains are in general to be observed as occur in the environs of Tortworth; I have not, however, met with either the Calymene variolaris, or the non-descript trilobite of that district; while the Asaphus caudatus is common, and in one instance the Calymene of Blumenbach has occurred, namely at Aston Ingham adjoining May hill, where it was discovered by the Rev. Dr. Cooke. Chain coral, on the other hand, is much more abundant. Portions of the Cyathocrinites rugosus are also occasionally met with.

The beds of the transition series appear under different angles of elevation, in their line of contact with the old red sandstone on the west, dipping in some parts at a low angle toward that quarter, as at the north-eastern foot of Perrystone hill; while in others, as at Aston Ingham, they approach to the vertical position.

§ 35. On the other hand, the old red sandstone, in its line of contact with the transition tract, is generally disposed in strata approaching to the horizontal position, dipping 15° to 30° toward the west; but in receding from the transition district, the strata gradually obtain a higher angle of elevation, even so high as 70° in the sandstone ridge east of Mitchel Dean; corresponding, in this respect, with the arrangement already observed on the right bank of the Severn, in connexion with the Forest of Dean (§ 17.).

In the lower strata of the old red sandstone, adjacent to the transition rocks, may be casually observed a few beds of limestone conglomerate, composed of irregularly angular pieces of limestone and slate-clay compacted by a marly or calcareous paste, and locally known by the name of *cornstone*. Similar beds, and also a few of limestone, were met with in the lower strata of the old red

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grayish, yellowish, and greenish, as are displayed by the old red sandstone of the sedimentary class; these sandstones likewise being either nearly free from mica, or more or less micaceous, particularly on the planes of separation.

These beds appear to constitute the mass or nucleus of May hill, Huntley hill, and Nott's hill; being occasionally separated by thin beds of clay or sandy micaceous slaty clay, in some places penetrated with calcareous matter, and more or less firm and consistent.

The impressions and casts of organic remains occur in the coarse grained sandstone, as well as in the finer grained, and in the slate-clay; and the same coralliform protuberances that are so often met with in those of the Tortworth district appear on the surface of both.

The conglomerates and sandstones thus found in the transition period, might perhaps by some geologists be denominated gray-wacké. But if we are to speak a language that shall be generally intelligible, it becomes necessary to confine the use of that term, and of gray-wacké-slate, strictly to such rocks as possess a compound mechanical structure, with a base of clay-slate either pure or quartzy. The evils arising from a loose application of these terms are so sensibly felt, that the word *gray-wacké* has become, in a manner, the opprobrium of geology.

sandstone, in driving the Bullo Pill Tunnel, which traverses Hay hill near Newnham, being about 1200 yards in length.

§ *36*. In ascending the north-eastern escarpment of the Forest of Dean coal-basin from Mitchel Dean, we find the old red sandstone supporting the carboniferous limestone, both dipping 60° toward the south-west; toward the escarpment on the north-western side of the basin, as at the Trigg quarries, the general dip is 45° toward the south-east; but at the northern end of the ellipsis, and in the escarpment below the elevated and prominent point of Lea Bailey hill, the dip is 20° to 25° toward the south; so that here, as in the Cromhall coal-basin, the lowest angle is found at the northern end of the basin, while on the south-east and south-west the strata gradually acquire a greater elevation. In the tract extending from the foot of the northern escarpment to Perrystone hill on the north, a distance of six miles, the old red sandstone is still found, dipping at first 20° to the south, but subsequently it becomes almost horizontal, or gently inclined to the south-west or west.

§ *37*. The old red sandstone displays here, in general, the same characters as have been described in speaking of the environs of Tortworth, including also some subordinate beds of sandstone conglomerate.

The carboniferous limestone may be distinguished into two masses, a lower and an upper one. The former is composed of blueish-gray compact limestone in frequent alternation with beds of slate-clay and marly clay; the organic remains contained in which are analogous to those met with in the Tortworth district:—among these are found also remains of the Rhodocrinites verus and Cyathocrinites planus. The upper and more considerable mass consists of magnesian limestone, fine and minute foliated granular, and of purplish, reddish, yellowish, and grayish colours, disposed in continuous strata, and free from other beds. Hæmatitic iron ore is found in the magnesian limestone, and has been wrought by mining operations at various periods.

The limestone supports the bed of sandstone and sandstone conglomerate which forms the immediate base of the Forest coal-basin; in this respect also coinciding with the relations of the Cromhall coal-field.

According to Mr. D. Mushet of Coleford, the beds of the Forest coal formation are between 300 and 400 fathoms thick, in which are distributed twenty-eight seams of coal, constituting together a body 50 feet 5 inches thick. Of these, fourteen seams vary, from 1 foot 10 inches to 5 feet in thickness, forming together 36 feet 7 inches of coal. The remaining fourteen seams vary from 4 inches to 1 foot 6 inches in thickness.

III. NORTH-WEST OF SOMERSETSHIRE.

General Relations.

§ 38. The north-west of Somersetshire, included between the Bristol Avon on the north and the river Parret on the south, may be generally described as composed of three ranges of hills, with intervening valleys, observing a direction nearly from east to west;—the Leigh Down, the Broadfield Down and Dundry, and the Mendip range; the first and second of these chains being separated by the vale of the Avon, Ashton, and Nailsea, and the second and third by that of the Yeo; while on the south of the Mendip chain are found the extended plains, through which flow the Axe, the Brue, and the Parret.

This form of the surface has a near connexion with its geological structure, which presents three great undulations from north to south,—though much modified and interrupted, by abruption, the superposition of newer formations, and partial denudation. These tracts, connected with the southern parts of Gloucestershire, are in like manner composed of the first and second series of the sedimentary class, and in part also of the third series. (See the Section No. 5.*) My examination of them has been confined to the west of a line drawn from the Bristol Avon through Stanton Drew, East Harptree, Chewton Mendip, and Wells, to the river Parret. I now proceed to give the results.

§ 39. The general form of the western portion of Mendip may be thus described. Its highest part, which includes Black Down, presents a smooth uninterrupted surface, for a considerable way down either declivity on the north and south: ravines then begin to appear, which in descending are enlarged into defiles or combs. On the southern side, in particular, the range is intersected by the deep defile of the Cheddar cliffs, which in ascending to the north ramifies into those sinuous dells and ravines that mark the southern face of Mendip. On the northern side appear the two deep combs of Burrington and Dolborough;—both enter Mendip nearly at right angles with the vale of the Yeo, and both subsequently follow a course to the south of east, almost parallel to the range, with a broken escarpment facing the south; but in ascending to the eastward they merge into the general surface. Into Burrington comb, two ravines find their way, furrowing the northern face of Mendip; and, in like manner, a third ravine enters Dolborough comb, to the east of the village of Roborough. But to the west of that meridian, the aspect

* In this Section a few objects that do not stand immediately in the line, are projected upon it. The highest part of Mendip is, according to the Ordnance Survey, 999 feet above the level of the sea.

of Mendip changes. From its central part, a continuous ridge, with a corresponding dell on either side, projects to the westward, gradually declining to the vicinity of Sidcot; where the two dells merge into the valley, that finds an outlet on the south of west, between Crook's Peak and Bleadon hill. North and south of that valley and its eastern dells, are two ridges, with broken escarpments respectively facing the south and north; while to the west the vale is bounded by Bleadon hill, standing in immediate connexion with the northern ridge.

§ 40. The nucleus of Mendip consists of the old red sandstone; which occupies the highest part of the range in Black Down, extending from the meridian of Blagdon on the east, to that of Roborough nearly, whence, forming a distinct ridge, it gradually sinks into the vale at Sidcot; but further west it re-appears in the vale, for the distance of a mile, between Winscombe and Barton. In the more central part of Mendip, the old red sandstone is again seen in Nine Barrow Down, and about three miles to the north of Wells, extending in the direction of Chewton Mendip.

The sandstone of the Black Down range supports on its northern and southern flanks a body of slate-clay, which is succeeded by continuous carboniferous limestone, all in a conformable position. It is distinctly arched from the west of south to the east of north, being nearly flat in the crown of the arch. The sandstone strata dip, on the northern side, at angles gradually increasing from 7° to 30° and 40°, and lastly, where in contact with the slate-clay on that side, to 47°; but on the southern side they support the slate-clay under an angle of 26° to 40°. The former arrangement may be seen in the ravines connected with the combs of Burrington and Dolborough: the latter, in the bye-road to the east of Winscombe church, and in the ravines on the southern side of Mendip.

The slate-clay on the northern side dips in general 52° to the east of north; and that on the southern side apparently 26° to 40° to the west of south.

The limestone on the north and south of this elevated part of Mendip forms a continuous body, which sweeps round the eastern extremity of the high sandstone ridge, being in that quarter in close contact with it; but to the west of the meridian of Roborough, the limestone is greatly abrupted and recedes from the sandstone, forming, on the north and south of the inclosed valley, the broken escarpments and the dells already mentioned. On the southern side of the highest part of Mendip, the limestone dips generally 20°, at first to the south 35° west, and subsequently to the south 20° west, as far as Cheddar, a distance of three miles; but in the western direction, extending toward Crook's Peak and the southern side of Bleadon hill, the dip is to the south, 30° to 38° west, at an angle of 30° to 36°. On the east of the high sandstone ridge, the strata, both of the sandstone and limestone, are gradually inflected from the south to the east, and then to the north. The limestone is thus spread over Mendip, in a space of three miles, as far as the road that traverses the range from West Harptree to Wells; in which expanse I have traced its dip, at angles varying between 8° and 25°, from the south 38° west, to the south, south-east, and east; and to the east 40° north, at an angle of 15°; this last observation having been made on the top of the descent above West Harptree. To the east rises a second eminence of sandstone, not much inferior in elevation to the former, but of a different character.

If we now return to the west along the northern body of limestone, we find the dip of its strata gradually increasing, until in Burrington comb they are inclined to the north 38° east, at an angle of 56° when in contact with the slate clay, and of 65° in the crest of the escarpment. From hence, they maintain a similar position, in a nearly rectilinear course, through the ridge of Dolborough, Sandford, and Banwell, toward Hutton and Uphill; dipping in the ridge, at angles varying from 65° to 78°, to the north 15° to 25° east. This range of limestone gradually declines in elevation from the meridian of West Harptree on the east, past Burrington, to Banwell on the west; but from hence it rises again gently toward Bleadon hill, though with some interruption near Hutton. On the top of that hill, the stratification appears nearly horizontal. Hence, coupling this observation with those made on the north and the south, it is highly probable that the arch of limestone is as continuous in Bleadon hill, as it is to the east of Black Down or of the meridian of Blagdon.

Besides the general arrangement, now described, I have to notice a partial inflection in the northern body of limestone. In the Dolborough ridge, the strata dip 65° to 70°, toward the east of north; but in the northern declivity of the hill, and at the entrance of the comb, they gradually acquire a vertical position, and then open like a fan, dipping, at the outlet into the vale of the Yeo, at so low an angle as 10°, to the south 38° west. This is in fact the commencement of a small undulation, which may be traced to and through the low hill of Church hill, which stands out in the vale, and ranges nearly parallel to the main limestone ridge; the strata in that hill being inclined to the south-west and north-east on its opposite sides. I am informed that a similar disposition is observable in Worl hill, which is situate in the same line of range, adjacent to the channel.

§ 41. The old red sandstone, which re-appears in the range to the north of Wells, dips also on the north toward the east of north, and on the south toward the west of south, supporting the limestone in a conformable position. The latter rock continues to the southern declivity of the range; where a body of slate-clay makes its appearance, containing thin layers of limestone, and also alternating with it in mass.

§ 42. Let us now consider the general characters of the old red sandstone, slate-clay, and limestone.

In the lowest visible portions of the old red sandstone of Mendip occur some beds of sandstone conglomerate; and the common characteristics of the formation are much the same as those of the environs of Tortworth and the north-west of Gloucestershire;—with this exception, that clayey, marly, or 'cornstone' beds are no where exposed to view, but layers of reddish slate-clay, from six inches to one foot thick, are partially interstratified with the sandstone. In this fundamental sandstone I have no where observed any organic remains.

The sandstone, where adjacent to the superincumbent slate-clay, is sometimes traversed by numerous small filamentous veins of calcareous spar, and in some places it contains portions of carbonate of lime; as in the Roborough ravine, and in the road east of Winscombe church. And in the western ravine connected with Burrington comb, I found its substance penetrated with carbonate of lime to the depth of three or four fathoms; the fracture of the compound being compact, and of a blueish gray colour, while the exterior coating appears as a yellowish, or reddish, friable sandstone, arising from the loss of the carbonate of lime by weathering.

The northern body of slate-clay, which, in the Burrington ravines, appears to be about 150 fathoms thick, contains at first, incidentally, thin subordinate beds of grayish and reddish sandstone and limestone, from one inch to two feet thick, with which it alternates; but on approaching the continuous limestone on the north, limestone becomes interstratified with it in thicker beds. In this alternating series, a reciprocal incorporation of the substance of adjacent beds frequently takes place, either in a distinct form or indiscernibly; and in all the varieties, minute scales of silvery mica are more or less disseminated: but the purest beds of limestone in the slate-clay are found in the vicinity of the continuous limestone, and the most sandy near the fundamental sandstone. On the other hand, the interstratified beds of sandstone are seldom void of carbonate of lime, except when in a partial state of decay; constituting in their sound state, a grayish firm compact rock, of a quartzy nature, and, in the decomposed form, a yellowish or reddish sandstone, more or less coherent, in which the casts and impressions of organic remains are particularly distinct. The slate-clay is more partially penetrated with carbonate of lime, or with sandy particles. All these beds contain organic remains, similar to those that occur in the continuous limestone, particularly spiriferites, terebratulites, and entrochites, with some corallites; and I have met also with one small orthoceratite. The slate-clay, however, contains such remains much more rarely than the other beds.

The southern body of slate-clay, which seems of smaller dimensions, but not determinable, appears under analogous circumstances, wherever sufficiently exposed to admit of observation, as in the bye-road to the east of Winscombe church. Upon this range of slate-clay, fruitless attempts were formerly made to discover coal.

The continuous limestone on the southern side of Mendip is generally disposed in strata varying from six inches to five feet thick; on the northern side, in strata from six inches to three feet thick. It is commonly of a blueish gray colour, sometimes tinged with black, and more rarely, mottled with red; and is not unfrequently fetid. It contains incidentally slight layers and masses of hornstone and lydian stone; and also beds of magnesian limestone, of variable thickness. The limestone of the northern range, as traversed by Burrington comb and the ravines connected with it, appears to be about 600 fathoms wide. In its central part is interposed a bed of magnesian limestone, about ten fathoms thick, of an ash gray colour, granularly foliated or compact, and when in a state of disintegration, resembling sandstone. But more to the west, in the Sandford and Banwell portions of the ridge, the magnesian limestone obtains a much more considerable width, probably not less than one hundred fathoms. It here exhibits reddish brown, ash gray, and buff yellow colours, and frequent cavities lined with crystals of calcareous spar. The organic substances which it contains consist principally of caryophyllites. Beds of magnesian limestone are also to be met with in the southern range; e. g. adjacent to the road leading to Cross, and in the southern side of Bleadon hill. Its most common structure is the minute-foliated granular.

The organic remains which I have observed in the Mendip limestone are the following *:—

* It may be useful to notice in this place the remains of fish that have been met with in other parts of the world, both in the carboniferous limestone and in the coal formation:

In *England*,—as above stated, and palates and bones near Bristol, in the carboniferous limestone. (Geol. Trans. Vol. IV. p. 198 and 200.)

In *Scotland*, impressions of fish, and teeth of fish in the limestone of the coal formation. (Essai Geologique sur l'Ecosse, par Boué, p. 172, 195.)

In *Ireland*, casts of the concavity of the vertebræ of fish, in the limestone near Cork. (Mr. Miller's collection.) In

Of *vertebrated animals,*—the small palate of a fish, found in the lower part of the continuous limestone on the southern side of Burrington comb.

Of *crustacea,*—four specimens of a trilobite, from the same locality, being the tuberculated species depicted by Brongniart (Plate IV. fig. 12. Histoire Naturelle des Trilobites), and which was derived from the Dublin limestone *.

Of *univalves not chambered,*—a depressed species of Cirrus, a Helix, and a Turbo; of *bivalves,* anomites, terebratulites, spiriferites, and productites; of *echinites,* the spines; of *crinoidea,* portions of platycrinites, actinocrinites, and rhodocrinites; and of *coralloid remains,* caryophyllites, astreites, tubiporites, and a species of Turbinolia.

§ 43. The effects of a destructive power, as shown in the abruption of escarpments and the excavation of defiles and valleys in the Mendip range, are also manifested by reproduction from their debris. The inclosed valley and dells on the west of the meridian of Roborough, and the ravine which winds up the northern face of Mendip on the east of that village, both bear evidence of this fact. In the latter may be observed a considerable deposition of the calcareo-magnesian conglomerate, which, ascending a considerable way up

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In *Lower Silesia,* impressions of fish in the limestone of the coal formation, near Kernzendorf and Rupersdorf. (Von Raumer, über das gebirge Nieder Schlesiens, &c.)

In the *Forest of Thuringia,* impressions of fish, in the coaly shale of the coal formation near Goldlauter and other places; and in the coal near Klein Schmalkalden and Mannebach. (Freiesleben, Geognostischen Beytrag, &c.)

In *Sarrebrück,* impressions of fish in the clay-ironstone of the coal formation. (Von Schlotheim, Petrefactenkunde, p. 30; and Description of the Royal Museum of Natural History at Paris, by M. Deleuze, English translation, p. 249.)

Impressions of fish in the coal formation of the Hundsdrück are noticed also by M. Beurard in the Journal des Mines, Vol. IV. p. 409.

In *North America,* fossil fish in the sandstone of the coal formation of the Ohio, in the basin of the Mississippi. (Cleveland's Elementary Treatise on Mineralogy and Geology, Vol. II. page 511.)

* This species of trilobite seems characteristic of the limestone and slate-clay of the carboniferous series; occurring also in the carboniferous limestone of Caldy Island [a], in that of Bristol and Cork, as observed by Mr. Miller; and apparently also in the carboniferous limestone of the Isle of Man [b], Kendal [c], and Dumfriesshire [d]; and in the carboniferous shale of Anglesea [e] and Holy Island [f].

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[a] Catcot's collection in the Bristol library.

[b] Professor Henslow; Geol. Trans. Vol. V.

[c] Sowerby's Min. Conchol. Vol. I. p. 129.

[d] Ibid. Vol. III. p. 83.

[e] Sowerby, Min. Conchol. Vol. IV. p. 32. & pl. 329.

[f] Mr. Greenough, Geol. Map of England and Wales.

the ridge of the old red sandstone, is thence spread through the parishes of Roborough and Shipham, extending into the valley on the west. The calcareous conglomerate, thus overlying the old red sandstone, slate-clay, and carboniferous limestone, dips in the lower strata 33° toward the west, but the higher strata soon acquire an horizontal arrangement. I have represented this position of the conglomerate in the vicinity of Shipham, in the small Section, Plate XXXIX., placed below that part of Section No. 5 with which its structure corresponds.

The flanks of Mendip also testify the same destructive agency. On the southern side, the calcareous conglomerate forms an exterior border of low hills, ranging along its foot, the extended strata of which gently inclining toward the south, descend low into the plain. This structure may be distinctly observed in proceeding from Wells to Easton, Westbury, and Rodney Stoke; but before we reach Cheddar and Axbridge, the high conglomerate border has merged into the vale. To the southward the conglomerate is succeeded by new red clay marl, which supports lias in the form of truncated cones,—as in the knolls of Cheddar and Brent,—the latter surmounted by a cap of oolite; or in narrow extended ridges, as in those of Weare and Badgworth; while still more south, in the Polden hills, the lias ridges acquire greater importance. The prevailing sub-soil of the rich vales of the Axe, the Brue, and the Parret, is probably throughout, like that of the vales of Gloucester and Evesham, either new red clay-marl, or lias.

On the northern side of Mendip, the declivity is faced high up by a great deposition of the calcareous conglomerate; which forms the immediate brow of the range, and attains to a considerable elevation between East Harptree and Burrington: but further west it gradually declines, skirting the foot of the hills, and sinking into the vale. I may here observe, that the calcareous conglomerate itself bears the marks of the same destructive action, as the older rocks from whose materials it was derived *. Of this the beautiful defile of Rickford, through which the public road passes from Blagdon to Langford, is an example; being scooped out of this formation, the opposite sides corresponding in salient and re-entering angles. The calcareous conglomerate is here, as in many other quarters, disposed in firmly consolidated horizontal strata, each about four feet in thickness.

§ 44. Before I leave Mendip, I must notice the high eminence of sandstone, which rises in the range above East Harptree, and to which I have already adverted (§ 40.). The strata of this rock are horizontally disposed, and in

* The origin, however, of these appearances may be referred to different periods.

general one, two, and three feet thick; and they are separated by thin irregular layers of clay, from half an inch to one and two inches in thickness. Some of the beds of clay, however, extend to one, two, and three feet in thickness; and being much charged with particles of yellow ochre, they are wrought for the sake of that substance, from which a pigment is prepared, by means of pits sunk two or three fathoms in depth. The sandstone consists of the following varieties:—

1. Yellowish, grayish, and reddish white, minute-granular sandstone; composed of particles of quartz closely aggregated. This passes into

2. Compact quartzy sandstone, or quartzy rock, of similar colours; and this into

3. Compact splintery hornstone, pale blueish and yellowish gray, grayish and yellowish white.

4. A siliceous breccia, composed of small fragments of sandstone, with differently coloured pieces of hornstone and quartz, and grains of felspar; in a specimen of which I found an entrochite, consisting of siliceous matter. I have observed this compound firmly adherent to the fine-grained yellowish white sandstone, No. 1, and in a parallel position; the different members of this series being probably interstratified with each other. But the prevailing character of the rock is that of quartzy sandstone or quartz-rock, and hornstone; while in the brow of the hill above East and West Harptree, may also be observed masses of a siliceous conglomerate; a base of hornstone enveloping fragments of quartzy sandstone and hornstone *.

5. Yellowish and ash gray porous fine-grained sandstone, composed of grains of quartz, with a few scattered minute spangles of silvery mica.

6. The preceding sandstone, more or less charged with carbonate of lime, passing into a sandy limestone, and sometimes of a friable consistence.

7. Dull compact limestone, containing a few sandy particles and scales of silvery mica; and sometimes exhibiting minute dendritic delineations.

In the sandstones No. 1. and 2. casts and impressions of shells occur; which, though often obscure, are referable to a species of ammonite, a turbinated shell, the Pecten quinquecostatus, a Modiola, a Pinna, an Astarte or Venus, and one or two species of Ostrea. Of these the casts of the Astarte, and the impressions of the Modiola, are the most common. Crinoidal remains also occasionally appear under the same circumstances.

In the sandstones No. 5. and 6., impressions and partial casts of a species

* Some of the Druidical stones at Stanton Drew consist of the conglomerate No. 4; while others are composed of No. 5.

of bivalve are particularly abundant, apparently derived from a Tellina or a Donax. And in the sandy limestone No. 7. I have observed a few fragments of small bones, of an indeterminate character.

This formation of sandstone is bounded by the carboniferous limestone on every side, except on the north-eastern declivity, where the calcareous conglomerate prevails; but its position with respect to those formations is not distinctly shown by actual contact in that quarter. From the extended researches, however, of the Rev. W. D. Conybeare and Professor Buckland, it appears evidently to be of later origin than either of them; since in a direction more toward the south-east, two small eminences of a similar sandstone are to be observed, reposing upon the calcareous conglomerate that partly covers Mendip adjacent to the defile leading to Charton Mendip:—a view, which has since been confirmed by my own personal investigation. The three eminences of cherty sandstone, therefore, though of rather doubtful relations, may perhaps be considered as most nearly allied to the iron and green-sandstone formation, and as outlying portions of that which is found in the regular order of succession above the oolite, in the east of the county, and in the adjoining parts of Wiltshire.

§ 45. From the north-eastern front of Mendip, between Blagdon and Burrington, the calcareous conglomerate extends quite across the valley to the north; acquiring in the higher strata a finer grain, and passing into a compact limestone often of an earthy aspect, which forms beds of an argillaceous, sandy, or magnesian quality, that support and in some places alternate with the marl and clay of the new red sandstone formation:—which last, on the other hand, is succeeded in part by shelly lias limestone; as in the top of the isolated ridge of Aldwick, on the north side of the Yeo, where the stone is in horizontal strata, and has the aspect of a congeries of broken shells. The new red clay-marl in the lower part of that ridge, on which Aldwick Court is built, contains, as I am informed by Mr. Baker the proprietor of the estate, a considerable bed of white granularly-foliated gypsum.

On the northern side of the valley, the calcareous conglomerate is again seen in contact with the carboniferous limestone, flanking the Broadfield Down range on its south-western side, but declining from thence into the vale toward Wrington and Congresbury. It forms the eastern border of that range also in the direction of Butcombe and Winford, and again at the western base of the Dundry range, extending thence toward the vale of Ashton. Toward the Bristol Channel, the new red clay marl is found sustaining lias, in Wolvershill between Banwell and Worle, and in the vicinity of Locking and Weston: and the same fact may be observed, in the eastern direction, in the low hills which lie between the parallel of Butcombe, Winford, Dundry, and the Avon, and the western side of the vale that winds past Chew Magna, Chew Stoke, and Sutton, toward the vale of Harptree. In that vale, a coal tract is found; while the low straggling hills on the east, which intervene between the vale and the vicinity of Bath, appear to be composed of the new red sandstone formation, supporting lias partially surmounted by oolite; and on the west also, in the Dundry range, a portion of the lower oolite is superadded, constituting its upper part throughout.

§ 46. The Broadfield Down range is a vaulted inflection of limestone, nearly flat on the top, and inclined on the northern side, near Dundry, 25° to the north-east, and on the southern, at the brow of Red Hill, 25° to the south-west. This form is probably derived from that of the subjacent old red sandstone, which, however, I have no where seen within this range: but the limestone of Leigh Down range, which ascends to the north on the opposite side of the vale of Ashton, reposes distinctly on the sandstone, as is well shown in the course of the river Avon through those rocks. Broadfield Down is furrowed on the western side by Brackley and Gobble combs; and near the mouth of the latter, the strata are gently undulated on the large scale in an easterly and westerly direction. The limestone of both combs declines at an angle of 15° to 20°, into the vale which contains the Nailsea coal-field. The organic remains found in the carboniferous limestone of Broadfield Down are analogous to those of Mendip.

Local detached patches of the calcareous conglomerate occur also high up on the limestone, as in the upper part of the defile that proceeds from Brackley comb; and here it partly supports shelly lias limestone, similar to that of the top of Aldwick hill.

§ 47. The Bedminster coal-field on the south-western side of Bristol (Section, No. 5.), is overlaid by the second series of the sedimentary class, no part of the coal formation coming out to the surface. But its immediate foundation appears to be the same quartzy iron-shot sandstone as that of Brandon-hill; which reposes on the carboniferous limestone of Clifton and Leigh Down, dipping 30° toward the east of south, and corresponding in this respect with the broad belt of sandstone near Cromhall, of which it may be considered as the south-western continuation. In the Bedminster colliery are three seams of good bituminous coal, two of which are wrought, namely the deepest and the uppermost; the former being three feet four inches, and the latter two and a half to three feet thick, while the middle seam has a thickness of one foot only. The interval between the two principal seams is twenty-three fathoms. The roof of the coal is shale, and the floor indurated clay. The dip of the coal beds is, throughout this part of the vale, toward the east of south, at an angle of 20°. This colliery is at present worked by means of three shafts, of which the northern is eighty fathoms, the middle eighty-two fathoms, and the southern, one hundred and twenty-seven fathoms deep. The coal is cut out in the broad way.

§ 48. Metalliferous repositories are found in the carboniferous limestone, and in the calcareous conglomerate; and though of very different eras, both contain in general calcareous spar, quartz, sulphate of barytes, galena, calamine, brown ironstone, iron ochre, and black ironstone, with some manganese.

The repositories of ore, in the carboniferous limestone of Mendip and Broadfield Down, are beds ranging and dipping with the strata, and veins intersecting the series. Both are characterized by walls of white granularly foliated limestone, from which proceed on either side columnar concretions of calcareous spar, meeting in the middle; and both also sometimes consist of a beautiful congeries of balls, composed of columnar concretions radiating from a common centre, partly immersed in a base of granularly foliated limestone. These modifications of carbonate of lime form the principal substance of the beds and veins, and the connecting medium of the other ingredients.

In no part of Mendip, does any trace occur of former mining operations conducted upon a systematic plan; shallow pits appearing in most places, sunk near to one another, or a long line of excavations made, in open coast, at the surface. In few instances are the workings supposed to have gone to any considerable depth; and the common depth perhaps rarely exceeds twenty or thirty fathoms. Yet, in this manner, considerable quantities of galena and calamine have been raised at different periods, in many parts of the Mendip range, as well as in that of Broadfield Down. At present, little ore is raised in any part of the tract.

The calcareous conglomerate has likewise been the subject of mining operations, principally in the parishes of Shipham and Roborough, and also near Rickford and on Broadfield Down. The metalliferous portions of this formation are traversed by veins, in all directions, sometimes in such numbers as to constitute a kind of net-work on a large scale; the veins observing no regular order in the dip, but being sometimes vertical, and often inclined one way or the other indifferently. They vary in width from one to six inches, but are sometimes enlarged to the breadth of one, two, and three feet, particularly at the points of intersection. Few workings have gone to a greater depth in the conglomerate than twenty or thirty fathoms, and the extreme depth is said to be about thirty-five fathoms; depending perhaps in part upon the thickness of the bed of conglomerate, beyond which, in all probability, the veins do not penetrate into the subjacent carboniferous limestone, or into the old red sandstone.

§ 49. Mining operations have also been conducted in the new red sandstone and clay marl formation; namely, in that part which skirts the eastern borders of the Broadfield Down range. The upper part of this range, overlooking the vale in which is situated the village of Winford, consists of the carboniferous limestone. This is overlaid, on the brow of the hill, by a deposition of the calcareo-magnesian conglomerate, which is succeeded by the new red sandstone, both declining toward the vale. In the latter is found a bed of that kind of clay ironstone, called *reddle,* which varies in thickness, but in some places extends to five or six feet. To this bed, pits are sunk at convenient distances, commonly about eighteen yards in depth, and connected with each other by means of the underground operations, the bed itself being wrought by the pickaxe in the broad-way. The works are carried on during the dry season only, when they are free from water, being flooded in the winter by the subterranean springs. The reddle thus obtained is applied to various purposes; among others to the preparation of a pigment.

In concluding these observations, I shall merely add, that if we consider the old red conglomerate and sandstone, and the calcareo-magnesian conglomerate and sandstone, in a general point of view, with reference to their relative position, composition, and structure, both will be found to bear evidence of the violent disturbances which have taken place during the conformation of the crust of the globe. The former, compounded of the detritus of more ancient rocks, are spread over formations of an earlier era, reposing upon and extending from those of the transition period, to the fundamental granite itself; their composition varying more or less according to the constitution of the tracts upon which they border: and the calcareo-magnesian conglomerate also varies in a corresponding manner, when reposing on the carboniferous series, or spreading from thence to the confines of the transition and primary formations. Analogous considerations apply to the conglomerates and sandstones which are partially found in the transition and primary epochs; but with increasing force to those of the later periods in the geological succession,—the new red sandstone, the iron and green sandstone, and the gravel and sandstones of the fourth or last sedimentary series. If such effects attest a long-continued action of the ocean, subject at distant intervals of time to greater or smaller degrees of agitation; the abundance of marine remains distributed throughout the whole of the secondary series, from the transition beds up to the latest deposits of the ancient sea, demonstrate a similar action in a still stronger manner.

XVII.—*Extracts from a Paper entitled, Remarks on the Strata at Stinchcombe near Dursley, in Gloucestershire.*

By GEORGE CUMBERLAND, Esq.

[Read December 6th, 1822.]

On Hampton common and at the top of the Stroudwater vale, towards Cirencester, we have a fine oolite, nearly approaching in texture to Bath stone. Beneath the level of the upper oolite, at Uley great quarry, is a mass of bastard-freestone, differing from Bath stone in the abundance and yellowness of the calcareous matter by which it is cemented, and in being more porous and subject to flake after frost. It contains but few shells. Below this freestone are rubbly beds, consisting of compact sparry masses, irregularly shaped like chalk-flints, very full of shells, and separated from one another by a soft calcareous powder, tinged by iron.

The tops of Stinchcombe hill and the other hills in its vicinity that flank the valley of the Severn, exhibit vast heaps of rubble, consisting of bastard-freestone mixed with some fragments of pure white oolite. The organic remains that we here find are three or four species of Anomia, Trigonias dædalea and costata, Ostrea crista-galli, and Porpitæ.

Beneath this debris, in a quarry on the northern side of Stinchcombe hill, under a high beech-wood, we see a few horizontal beds cropping out from beneath others of the above-described rubbly oolite. These beds are of a warm brown colour, and are rather compact in texture, consisting of a sandy loam (such as here prevails upon the surface) cemented by calcareous spar. These beds are divided into strata of moderate thickness. In the beds themselves but few shells can be distinguished; but their joints are full of the casts of Myæ and Cardia of large dimensions, mixed, occasionally, with a few small Pectens.

The passage from the preceding beds on the sides of the hill to the brown beds at Stinchcombe in the valley below, is best exhibited in a hill called Long Down, above the little village of Upper Cam. At the top is a quarry of white stone: the road leading up to this quarry cuts through a deep stratum of soft brown sandy stone: beneath this lie the harder masses of the brown shelly rock, so well exposed at Newnham quarry and at two other quarries, all situated in the parish of Stinchcombe.

Newnham quarry is about one mile and a half distant from Dursley. Its strata correspond very nearly to those of Dundry hill on the south of Bristol, though at Dundry we meet with few or no pentacrinital remains. The uppermost of the strata at Newnham consist of brown ochreous iron-shot sandy oolite, blended with calcareous spar. They contain an abundance of organic remains viz. Myæ, Pinnæ, three or four species of Anomia, casts of trigoniæ, ammonites, belemnites, pentacrinites, and fossil wood. The lower and more solid strata contain the stems of two species of pentacrinite, distinguished by their whiteness from the brown mass in which they are imbedded, and often well displayed on the weathered surfaces of the rock. In these strata we also find three or four species of belemnite, which are easily detached in consequence of their polished surfaces. We have also the Anomia sulcata, which sometimes parts with its exterior coat, and then appears with a fine silky lustre. The spined Anomia and spined Ostreæ can never be obtained perfectly clear of the rock.

Under these ochreous beds we almost every where meet with a whitish or drab-coloured clay, occasionally interstratified with beds of blue clay, and forming itself into somewhat indurated concretions. In these concretions we find Myæ, Anomiæ, and three or four species of ammonite, which may easily be detached by a slight blow of the hammer, and then frequently retain their originally nacre. These argillaceous beds are found at the depth of ten feet at Newnham quarry. They lie nearer the surface at the mill of Messrs. Shepherd and Hawker at Uley, where in the year 1821, while enlarging the water-course, the workmen cut through the ochreous beds, full of shells, into those of clay, from which they turned up numbers of ammonites and other organic remains. The clay-beds are also seen in a water-course at Leonard Stanley under Frocester hill, at Cam, and at several other places below the Cotswold. In these retentive strata the springs appear, and wherever the clay occurs beneath the brown and ochreous beds, good water is found.

Beneath the foregoing beds we must place those of the blue lias, so well exhibited at Fretherne cliff on the Severn. The uppermost strata consist of slaty clay, in which gryphites are contained. Below them is a bed abounding in a peculiar pentacrinite, of which no head has yet been found, that I am aware of, except an injured specimen in the collection of Mr. George Hawker of Stroud. We can walk at low-water on the blue lias of Fretherne, to the extent of half a mile, as on an extensive level floor, and there see enormous ammonites under our feet, some exceeding four feet in diameter. In the lias is found jet, with calcareous spar traversing its cracks.

In the vale of the Severn we find red marl, which probably at some depth contains beds of salt; for at Ashton Somerville, at Child Wickham, and at Sandhurst, all lying on the same line near to Gloucester, brine springs have been discovered, though never worked.

XVIII.—*On the Crag-strata at Bramerton, near Norwich.*

By RICHARD TAYLOR, Esq. of Norwich.

[Read June 20th, 1823.]

IT is well known that an extensive district, commencing near Harwich and occupying nearly all the eastern coast of Suffolk, contains a substratum, several feet in thickness, of the crag-pit shells, which are used in many parts of that district for agricultural purposes. Many of them approach in their specific characters to those shells which are discovered upon our shores; while they are associated with others whose species have ceased to exist. Together with the shells are buried the remains of unknown animals. The Suffolk crag, particularly that in the vicinity of Ipswich, has furnished an extraordinary abundance of fossils to collectors, far exceeding in number those which we are able to present from Bramerton.

From Lowestoft to Bramerton, the crag shells are concealed beneath deposits of alluvial gravel, sand, and clay, of considerable but irregular thickness. To the east of Bramerton they have not, I believe, been recognised; to the west they may be observed at Whitlingham, immediately in contact with the chalk; they may also be traced forming thin beds above the chalk on the opposite side of the Yare at Thorpe, and are not unfrequently met with, several feet below the surface, on sinking wells in the city of Norwich. To the west of Norwich I have not hitherto discovered them, but to the north they may occasionally be observed at a few intermediate points between that city and Cromer. The valley of Wroxham, like that of Norwich, is sufficiently deep to intersect the crag, and to expose the chalk-strata, which here have attained a considerable elevation, and rise through the alluvial beds to a level with the surrounding country. At Cromer the crag passes into the sea immediately to the west of the jetty, and huge agglomerated beds of it may be observed scattered upon the beach at low-water mark. From these masses the best specimens of shells may be collected. They consist chiefly of a small Mactra, probably Mactra arcuata, and of Turbo littoreus, mixed with fragments of Mya lata, of Cardia, and of Balani. The crag shells are continued along the cliff about a quarter of a mile. Their position may readily be distinguished by the continual tendency of the sand, in which they are imbedded, to slip down, and to form heaps at the base of the cliff. The shells, in this as in most other cases, bear but a small proportion to the sand ; they appear chiefly in small fragments, few, if any, perfect specimens being obtainable.

No place along the course of the stratum that we have here traced, is so favourable to its examination as Bramerton, nor is there any, where its organic remains are so abundant or so well preserved; and accordingly its outcrop at this place has supplied several naturalists, and in particular Mr. William Smith and the late Mr. Sowerby, with excellent specimens of its fossils. There are some species however, particularly those belonging to the genus Mytilus, which, however perfect in form and colour, are too brittle to be taken out entire.

The accompanying sketch represents a section of the crag-strata, as they actually appear at Bramerton, on the southern bank of the river Yare, resting on the upper chalk. This is the deepest section in the county of the more elevated strata. The annexed table contains the thickness of each stratum, and a catalogue of the fossils is subjoined, both of such as I have observed myself and as have been obtained by Mr. W. Smith and Mr. Sowerby. Numerous as are the species, it is probable that many have escaped my observation ; and others have been purposely omitted, from my imperfect acquaintance with their names and specific characters.

TABLE.

Stratum.	Thickness. Feet.	
1	5	Sand without organic remains.
2	1	Gravel.
3	4	Loamy earth.
4	$1\frac{1}{2}$	Red, ferruginous sand, containing, occasionally, hollow ochreous nodules.
5	$1\frac{1}{2}$	Coarse white sand, with a vast number of *Crag-shells.*
6	$1\frac{1}{2}$	Gravel, with fragments of shells.
7	15	Brown sand, in which is a seam of minute fragments of shells, 6 inches thick.
8	$3\frac{1}{2}$	Coarse white sand with *Crag-shells,* similar to stratum 5. The Tellinæ and Murices are the most abundant.
9	15	Red sand, without organic remains.
10	1	Loamy earth, with large stones and *Crag-shells.*
11	1	Large irregular black flints, crowded together *in situ,* in the chalk. Adhering to these flints are echini, terebratulæ, inocerami, and belemnites.
12	15	Chalk, excavated to the level of the river adjacent.

Genus.	Species.	Variety.	Number of Plate in Sowerby's Mineral Conchol^{y}.	Number of the Stratum in which the shell is found.	Observations.
Emarginula	reticulata		33	8	
Turbo	littoreus	4 varieties	71	8	Abundant in stratum 8.
Scalaria	similis		16	5,8	
Trochus	similis ?		181	8	
	concavus ?		181	8	
Turritella	conoidea		51	8	
	trilineata (Smith)			8	
Murex	striatus		22	5,8	Abundant in stratum 5.
	......	carinatus	109	5,8	Sometimes with Balani attached.
	latus		35	8	
Cerythium	?			8	
Mya	lata		81	5,8,10	Mutilated specimens abundant in stratum 5.
Tellina	ovata		161	5,8,10	
	obtusa		179	5,8,10	
	obliqua		161	5,8,10	
	bimaculata (Smith)			8	
Mactra	arcuata		160	8	
	cuneata		160	8	
	dubia		160	8	
	ovalis		160	8	
Cardium	Parkinsoni		49	5,8,10	very fragile in stratum 5.
	angustatum		283	5,8,10	
	Edulina			5,8,10	
Mytilus	edulis			8,10	
	antiquorum		275	8,10	
Modiola	pallida		8	8	
Pectens	?			8,10	nearly an inch wide, with 20—25 rays.
Cyclas	cuneiformis		192	8	
Astarte	plana	3 varieties (Smith)	179	8	
Venus	lentiformis		203	8	
	equalis		21	8,10	
Nucula	Cobboldiæ		180	8	
Balanus	tessellatus			5,8	more common in stratum 5 than in stratum 8, both single and grouped.
......	crassus		84	5,8	
Fragments of lobsters and crabs				8	
Palates and vertebræ of fishes				5,8	
Fragments of bone				5	
Horns, vertebræ and teeth of large herbivorous animals				8	
Fragments of wood				5,8	
Fragments of coal				5,8	

XIX.—*On the Alluvial Strata and on the Chalk of Norfolk and Suffolk, and on the Fossils by which they are accompanied.*

By R. TAYLOR, Esq. of Norwich.

[Read May 2, 1823.]

1. *On the Alluvial Strata, above the Chalk.*

IN the present account of the alluvial strata and of the chalk I shall begin with the highest beds, proceeding from east to west.

Alluvial beds occupy the principal part of the surface of Norfolk and Suffolk. The extensive alluvial clays of those counties contain numerous waterworn fossils, which are exposed in excavations, or are found dispersed over the surface of the arable lands. In the retentive clays of High-Suffolk, these fossils consist of large belemnites, to which serpulæ are often found adhering, of the Gryphæa dilatata, Ostrea deltoidea, &c., and occasionally of the fragments of large ammonites and vertebræ. Mixed with these fossils are septaria and nodules of pyrites.

On the sides of the valleys which intersect these clay districts, we find beds of alluvial gravel, in which is a profusion of waterworn belemnites, either detached or inclosed in nodules of indurated clay. At Eye in Suffolk belemnites are mixed with elephants' teeth and other organic remains. Roydon gravel-pit, near Diss, on the northern bank of the Waveney river, abounds with belemnites, ammonites, echini and their spines, serpulæ, cardia, myæ, tellinæ, modiolæ, ostreæ, pectines, plagiostomæ, terebratulæ, inocerami, fragments of pentacrinites, and of bones. We there find Ostrea gregarea, Astarte planata, Venus turgida, Unio Listeri, &c.

Along an intermediate line between the high clay-lands and the outcrop of the chalk-strata, we find at Bury St. Edmunds, Weston, Hopton, Harling, Dunham, Wereham and Swaffham, in pits of clay and marl above the chalk, large blocks or boulders of a gray or greenish sandstone, distinguished by its peculiar fossils. These fossils are small, pointed belemnites; Terebratula ovoides, T. plicata and T. gigantea; casts of small ammonites; Avicula media; and species of the genera Trochus, Unio, Astarte, Venus, Tellina, Cardium, Isocardia, and Pecten. In the same pits with these boulders are found detached belemnites, similar to those of the high clay-lands, five species of ammonite, teredines in indurated clay, plagiostomæ, pernæ, modiolæ, pyritous fossil-wood, and hard orbicular septaria containing in their interior nautili or ammonites, much distorted by the crystallizations in the septa. With these occur, near Swaffham in particular, boulders of hard chalk, containing two species of belemnite, together with smooth and plicated terebratulæ, and mamillated echini. In the light lands in the neighbourhood of Swaffham is an abundance of flinty nodules, containing alcyonia and sponges, and marked with impressions of echini and their spines, inocerami, and terebratulæ. Upon the high edge of the chalk, at Marham, within a quarter of a mile of its western termination, we find in a very stiff alluvial yellow clay large blocks of a green sandstone, in which are imbedded Pecten orbicularis and P. cornea, Terebratula lata and T. ovoides, Trigonia aliformis, a species of Lutraria, pectunculi, and belemnites. In a mass of ferruginous sandstone found in the same neighbourhood, and belonging probably to these alluvial deposits, the fusiform belemnite with its alveolus, and two species of Pecten, have been discovered.

Over the chalk at Norwich, and to the north and west of the city, are thick beds of sand and gravel, with patches of alluvial clay and brick-earth interspersed. The sand, except where the crag-shells rest immediately on the chalk, seldom contains many or very perfect organic remains. The brick-earth yields only a few water-worn belemnites. The flints in the gravel are brown, gray, and (near the surface) colourless. They are shattery, breaking into fragments with the slightest blow of the hammer; and hence they are unfit for masonry or the fabrication of gun-flints, though unrivalled as a material for the repair of roads. On breaking the large gravel-flints found near the surface, both surfaces of the fracture are often seen lined with dendrites. Poringland hill and Mousehold heath, near Norwich, furnish an abundance of these arborizations. These flints contain the usual fossils of the chalk with layers of flint, as well as some others which have not hitherto been found in that stratum. Such detached fossils as are found, are usually silicified casts, the calcareous matter of the shells having disappeared. Thus of the belemnite, a flinty cast only of the cavity of the alveolus remains. The other detached fossils are trochi, inocerami, terebratulæ, pectines, plagiostomæ, cardia, serpulæ, echini, alcyonia, &c.

2. *On the Chalk.*

The most easterly point at which chalk has been traced, is on the coast, between Mundesley and Cromer, where we find two detached masses of soft chalk with numerous layers of flint, forming insulated cliffs of chalk*. Several circumstances lead me to consider these masses as the remnant of a stratum which existed further to the north-east in the space now occupied by the sea, constituting a higher part of the series than the chalk of Norwich. Some violent convulsion has evidently deranged the position of the chalk at these places. The layers of flint are about four feet asunder, and they undulate in a very remarkable manner. These masses are continuous with a solid bed of chalk discernible at low-water, reaching nearly a mile in length, from Trimingham to Sidestrand, and forming a level platform extending into the sea. Along this platform we see well displayed the parallel strata of flint, and the larger and least destructible of the fossil remains, such as the belemnites and echinites. The chalk of this platform is harder than that of Cromer or Norwich. The sea has now nearly washed away that part of the chalk-cliff which formerly abounded with that remarkable fossil shell presented by me to Mr. Sowerby, and by him figured under the name of Magas pumilus. That which particularly distinguishes this stratum is the vast abundance of a small curved oyster, called Ostrea canaliculata. Almost every part of the chalk is crowded with these shells, and many of the flints have from twenty to fifty of them adhering, which in that case, being hardened by the silex, afford the best specimens. The flints abound also with sponges and branching alcyonites, so numerous that scarcely one flint is found without some traces of them. In this stratum are found two species of Echinus; viz. a large Galea, and a Conulus from three quarters to one inch and a half in diameter; also spines of echini; a large obtuse, and a small fusiform belemnite; four species of Terebratula; pectines; Modiola parallela; dentalia; serpulæ; madrepores and fragments of pentacrinites, almost all of which fossils are peculiar to this stratum, and differ essentially from those of the chalk at Norwich.

A few miles to the north and west of this spot at Trunch and Cromer, detached portions of this chalk are worked for lime. At Cromer a large portion of chalk has been washed away by the encroachments of the sea; the point called by mariners *Foulness* being evidently the site of a former extension of the chalk-strata. The memorials of the former existence of this mass of chalk are heaps of ponderous chalk flints, which now form dangerous shoals for shipping. The fossils adhering to these flints resemble those of the chalk at Norwich.

The chalk in the neighbourhood of Norwich is characterized by its softness and whiteness; by its strata of flints, and by its fossils. It is best

* These insulated masses of chalk are noticed in Mr. Greenough's Geological Map of England.

displayed at Thorpe, at Whitlingham, and in the cliff of Bramerton. We have in a separate communication described the crag-strata which rest on the chalk at Bramerton. The chalk is here horizontal, and is exposed to the depth of about fifteen feet. Immediately on its surface reposes a stratum, one foot thick, of large irregular black flints, which contain many of the usual chalk fossils. Among the most remarkable fossils of the chalk are the tubiform flints, named by Professor Buckland *Paramoudræ*. They are commonly about three feet long, and pear-shaped with their smaller end (which is sometimes shattered into minute fragments) standing downwards. Their position is invariably at right angles to the parallel and horizontal seams of flint. Occasionally the lower end of one of the paramoudræ is placed vertically at the distance of two or three feet over the upper end of another; and in that case I have observed that the chalk in the interval is much impregnated with silex. When near the upper part of the chalk, they are sometimes filled more or less with sand; but usually with chalk, which then contains more silex than that in which they are imbedded. Numerous fine specimens of the paramoudræ are to be seen in the neighbourhood of Norwich, where they are used for posts. Other large masses of flint occur, upwards of three feet in diameter, the forms of which, however irregular, evince their organic origin, and lead us to refer them to some gigantic species of sponge or alcyonium. The other fossils which are found in the chalk at Bramerton or in its immediate neighbourhood are,

Echinites.	Spatangus	Cor maximum	
	———	?	(Smith, No. 3.)
	Conulus	depressus	
	———	albogalerus	
	Galea	ovata	
	——	pustulosa	(Smith)
	Cidaris,	a small mamillated species	
Terebratula	carnea Sowerby	15.	
	subundata	15.	
	plicatilis	118.	
	octoplicata	118.	
	intermedia	15.	
Alcyonium	conoides, and other species,		

besides three species of Ostrea, two of Inoceramus, three of Pecten, plagiostomæ, modiolæ, serpulæ, belemnites, sponges and flustræ. Mr. Smith further enumerates the species of echini, and the teeth, palates, and vertebræ of fishes

In the precincts of Norwich there is considerable variation at the different pits in the fossil products of the chalk. Thus in the pits at St. Giles's gates, ostreæ are most abundant; echini and the Terebratula plicata are most numerous and best preserved in the Pocksthorpe pits; large fragments of inocerami prevail most in those of Thorpe; pectines and trochi in those of Magdalen Chapel; while the belemnites and smooth terebratulæ are pretty equally diffused throughout them all.

At Letheringset and Holt, towards the northern coast of Norfolk, we find the chalk nearly similar in its substance and organic remains to the chalk at Norwich. At Thornham, further westward, it contains enormous paramoudræ, alcyonites, fragments of large inocerami, conuli and cidares.

The chalk in the excavations around Swaffham belongs probably to some intermediate bed between the upper and lower strata. It presents one peculiarity in the disposition of the layers of flint, two layers, forming a pair, being set at the distance of a foot apart, and each pair at the distance of several feet from the next pair. The chalk at Swaffham contains radiated pyrites and the following organic remains, viz. two species of Terebratula; Inoceramus Cuvieri from one to twelve inches long; plagiostomæ; two species of Patella; serpulæ resembling planorbes; spatangi; cidares and species of echinites; alcyonites; madreporites, teeth of fishes, and fossil wood. No belemnites are found in the chalk in this neighbourhood.

Seven miles to the westward of Swaffham, at Marham, we arrive at the western escarpment of the chalk, the lower beds of which are here extensively worked. These are less white and more dense than the superior beds, and are sufficiently hard for building, the church, the adjoining abbey, and a tomb within the church with recumbent figures, having been principally constructed of this material. The fossils of the lower chalk are a Spatangus; Discoides subuculus; Inoceramus Cuvieri; Chama? three or four species of Terebratula; a Gryphæa; a small Ostrea; a small Pecten; Ammonites Greenovii; flustræ attached to echini and inocerami; claws of the lobster; the teeth, jaws, and palates of fishes, and fossil wood. Belemnites are very rarely found.

The lower beds of hard chalk are completely exposed in Hunstanton cliff for the distance of a mile, the lowest stratum consisting of red chalk, which re-appears on the opposite coast of Lincolnshire. This red stratum is characterized by an abundance of very small belemnites. They seldom exceed one-eighth of an inch in thickness, and are from half an inch to an inch in length. They are largest in the middle; sharply pointed, smooth and polished on the surface, unusually translucent, of an amber colour, and sometimes pearly. The fossils of the hard chalk at Hunstanton nearly agree in other respects with those of the hard chalk at Marham.

XX.—*On the Strata observed in boring at Mildenhall in Suffolk: extracted from a Letter addressed to W. Somerville, M.D. M.G.S.*

By Sir HENRY BUNBURY, Bart. M.G.S.

[Read June 14th, 1822.]

Dear Sir,

As the Geological Society may wish to be informed of every circumstance that tends to verify the stratification in different parts of England, I send you an account of what has been observed in this parish on piercing with a boring machine to the depth of 270 feet. I will first give a short description of the country where the trial was made.

A part of the large parish of Mildenhall is fen-land, and belongs to the great Bedford Level. The substrata of the fens are not well ascertained; but I am inclined to believe that the blue clay, provincially termed gault, will be found in most places to lie beneath the peat. The remainder of the parish is upland, and has every where a substratum of chalk, which shows itself here and there even amid the fens. This chalk belongs to the range of that rock which passes from Cambridgeshire across this western part of Suffolk into Norfolk. The chalk contains no layers of flints, though covered by loose flints on its surface. It is generally hard enough to serve for a building-stone, if suffered to remain exposed for some months after being dug to the action of the air and frost. The surface soil varies very much; a large portion of it consists of a thin but rich sandy loam, while a more extensive tract is buried beneath a blowing sand. In hollows on the surface of the chalk-rock we often find deposits of blue clay, and occasionally of marl; and in one part of the parish are considerable beds of gravel and flint. The fossil remains are very abundant. We find water-worn alcyonia in flint; echinites both in chalk and in flint; palates of fishes in rolled pebbles of chalk amongst the gravel; many shells, and rarely the stalks of the pentacrinite.

A merchant of Norwich, who has established a small manufactory for winding silk in this village, hoped, by boring to such a depth as to meet with the water derived from a more elevated district, to obtain an overflowing well sufficient to turn a water-wheel; a similar experiment having been tried successfully at Cambridge. The water is found at the village in common wells, remarkably fine and pure at the depth of from ten to twelve or fifteen feet.

The chalk lies very near the surface on the spot where the trial was made, being covered by a rich sandy loam, to the depth of from twelve to eighteen inches only. The workmen bored through the common white chalk to the depth of thirty-five feet; and then through a layer having a yellow tinge and gritty to the touch, five feet in thickness. Below these lay the gray chalk, harder than the foregoing, and 136 feet thick. Next came blue clay, fifty-four feet thick, and then a layer of darker and heavier clay about ten feet thick, which approached in hardness to stone. This changed gradually into a stony mixture of blue clay with greenish quartzose sand, which was nearly of the same depth. Beneath lay ten or eleven feet of green sand, containing fragments of various fossils, and particularly of belemnites and pentacrinites. On descending, the blue clay re-appeared; but this lower bed abounded in fragments of large shells, having a high polish. The workmen had pierced through nine or ten feet of this clay, when the water of which they were in search rushed in, and the labour was discontinued. The water however, though it has risen in the shaft very nearly to the surface, has not overflowed; so that the experiment has failed of the intended purpose.

The action of the boring machine, and the small diameter of the perforation have been unfavourable to the ascertaining of the fossils of the several strata. Fragments of the stalk of the pentacrinite were the most perfect of the specimens. Among the broken fossils in the green sand, some were pyritical.

Recapitulation of the Strata.

	Feet.
1. Sandy loam	1
2. Common white chalk, without flints	35
3. Yellowish, gritty chalk . .	5
4. Gray, hard chalk . . .	136
5. Blue clay	54
6. Darker and harder ditto . .	10
7. Blue clay mixed with green sand	10
8. Green sand with many fossils .	11
9. Blue clay with fossil shells . .	9
	271

Believe me,

My dear Sir,

Very faithfully yours,

Henry Bunbury.

XXI.—*On the Discovery of an almost perfect Skeleton of the Plesiosaurus.*

By the Rev. W. D. CONYBEARE, F.R.S. M.G.S.

[Read February 20, 1824.]

I AM highly gratified in being able to lay before the Society an account of an almost perfect skeleton of Plesiosaurus *, a new fossil genus, which, from the consideration of several fragments found only in a disjointed state, I felt myself authorized to propound in the year 1821, and which I described in the Geological Transactions for that and the following year. It is through the kind liberality of its possessor, the Duke of Buckingham, that this specimen has been placed for a time at the disposal of my friend Professor Buckland for the purpose of scientific investigation.

At the period of my former communications it was natural and even just that in the minds of many persons interested in such researches, much hesitation should be felt in admitting the conclusions of an observer who was avowedly inexperienced in comparative anatomy; and there might have then appeared reasonable ground for the suspicion that, like the painter in Horace, I had been led to constitute a fictitious animal from the juxtaposition of incongruous members, referable in truth to different species. But the magnificent specimen recently discovered at Lyme has confirmed the justice of my former conclusions in every essential point connected with the organization of the skeleton.

The only material error which I have to correct relates to the bones which I supposed to be the radius and ulna: but with regard to the other parts of the skeleton, in assigning to the same animal the heads and vertebræ which had at that time never been found in connexion, and whose actual relation was therefore regarded by many as equivocal, in indicating the order and place of the several kinds of vertebræ, and in tracing the osteology of the humero-sternal parts, my opinions have received full confirmation. In the attempted restoration of the paddle also (though professedly given only on

* Some philological objections having been made to the composition of the word Plesiosaurus, I beg to state that it is formed on the very same principle as the words Ισαγγελος, Ισοδενδρος, &c., all of approved classical use.

conjecture), a very considerable approximation to the true structure of the part will be found, considering the very imperfect materials afforded by the fragments which had then been obtained.

But in addition to these particulars, which in all their material features were correctly stated, the specimen now exhibited presents others of a most novel and interesting character, not to have been anticipated previously to the discovery of a skeleton the whole exterior portion of whose vertebral column was perfect. I particularly allude to the neck, which is fully equal in length to the body and tail united; and which surpassing in the number of its vertebræ that of the longest-necked birds, even the swan, deviates from the laws which were heretofore regarded as universal in quadrupedal animals, and the cetacea. I mention this circumstance thus early, as forming the most prominent and interesting feature of the recent discovery, and that which in effect renders this animal one of the most curious and important additions which geology has yet made to comparative anatomy.

I now proceed to the details in the usual order.

Head.—The present specimen, and another of this part only, in possession of Miss Philpot, confirm the restoration attempted from the distorted head figured in Plate XIX. of the first volume of the second series of the Geological Transactions; and the latter extends our knowledge by exhibiting distinctly the occipital portion. We now also learn for the first time, that the head of this animal was remarkably small, forming less than the thirteenth part of the total length of the skeleton; while in the Ichthyosaurus its proportion is one-fourth. This proportional smallness of the head, and therefore of the teeth, must have rendered it a very unequal combatant against the latter animal; but the structure of its neck may perhaps be considered as a compensating provision, supplying it with the means of security and of catching its prey.

Vertebræ.—The distinctions between the cervical and caudal vertebræ have been fully and correctly stated in my former communications; but I had not at that time observed more than twelve of the cervical, whereas the present specimen exhibits about thirty-five, or, including the anterior dorsal, which were placed before the humerus and bore only five ribs, forty-one *. This great increase of the number of joints in the neck, is the more remarkable from the rigour with which nature appears, in most cases, to have enforced the law of a very limited number. In all quadrupedal animals, in all the

* It is difficult to assign the exact demarcation between these subdivisions of the column; because the inferior lateral or hatchet-shaped processes of the cervical vertebræ (which in this animal greatly resemble those of the crocodile) gradually become elongated, and assume almost insensibly the character of false ribs.

mammalia (excepting only the tridactyl sloths which have nine), the series is exactly seven; and so strict is the adherence to this rule, that even the short and stiff neck of the whale, and the long and flexible neck of the camelopard, are formed out of the same elementary number; the vertebræ in the former instance being extremely thin and anchylosed together, and in the latter greatly elongated. Reptiles possess only from three to eight cervical vertebræ; birds, approaching in this more nearly to the present species, but still falling greatly short of it, have from nine to twenty-three *, the number being the greatest in the swan. The ichthyosaurus appears to have possessed about eighteen cervical vertebræ; in fishes the ribs commence almost immediately behind the head.

The views of Geoffroy de St. Hilaire, that nature in the organization of the animal frame has caused the sternal portion to shift its position along the vertebral column, seem to derive an important corroboration from the structure of this animal; but it is remarkable that whereas the sternum holds a mean position in quadrupeds, and is thrown forward in fishes and backwards in birds, yet its position in this instance assimilates the plesiosaurus less to fishes, though destined to move in the same element †, than to birds, and exhibits at the same time a very wide departure from the type of the Saurian tribe. Although the number of the cervical vertebræ is thus unexampled, yet the length of the neck is nearly rivalled by another of the reptile class, namely the land tortoise. The length is in this case concealed by the anterior extension of the shell; the neck, however, notwithstanding its elongation, has only eight vertebræ. The general proportions of the tortoise, its length of neck, shortness of tail, and the smallness of its head, are in some degree analogous to what we observe in the plesiosaurus; but the structure of the head and teeth of the latter, and its want of shell, entirely negative the idea of its being

* The sparrow is said to possess only nine cervical vertebræ. (Cuvier's *Anatomie Comp.*) In aquatic birds the length of the neck, as well as the number of the cervical vertebræ, generally exceeds what we observe in the land birds, this construction enabling the former to procure sustenance in their own peculiar element.

† The Testudo longicollis, an inhabitant of fresh water and a native of Australasia, [see Shaw's Zoology, Vol. III. p. 62.] is the most remarkable among the tortoises for length of neck; and the figure of this animal in the work referred to, will serve to illustrate what in the Plesiosaurus must have been the external appearance of this part when covered with integuments. It would be very desirable to ascertain, from an examination of the skeleton, whether this species has more than the usual number of cervical vertebræ. Most of the tortoise tribe have the power of extending their necks considerably; especially the Testudo ferox, [see Shaw, Vol. III. p. 65.] whose neck, when exserted, is equal in length to the shell. By darting out this it is enabled to make even birds its prey.

intimately allied to the tortoise; and decidedly connect it with the Saurian order.

It will be necessary to subjoin a few words on the inferior hatchet-shaped processes which may be seen depending on either side from the lower part of the cervical vertebræ. Most animals present traces of these processes; they are particularly prominent in many of the long-necked quadrupeds, and in birds project into a long styloid branch: a rudiment of these may be observed in man, but I am not aware that any particular name has been assigned to them *. They have been sometimes confounded with the transverse processes, to which they often form a wing-like appendage. These processes are important, as serving to determine the number of the cervical vertebræ, and as affording very close analogies between the plesiosaurus and the crocodile; in both these animals these inferior hatchet-shaped processes are exactly similar in figure, and form separate pieces attached to the body of the vertebræ by a double stem: in the figures given of the cervical vertebræ in my former memoir, this stem alone and the double suture which receives it, could, from the imperfect state of the specimens, be represented; but I then expressed my conviction that the structure resembled that of the same part in the crocodile, and my conjecture is now verified.

The thirty-five anterior vertebræ of the plesiosaurus exhibit these processes distinctly characterized, and are therefore beyond all doubt cervical; in the six following the processes become lengthened, and gradually lose their hatchet-shaped extremity, assuming rather the form of false ribs, and should therefore perhaps be classed as anterior dorsal; but the whole forty-one are clearly placed before the pectoral extremities. In the crocodile there are seven cervical vertebræ with hatchet-shaped processes, and three anterior dorsal with false ribs before the humero-sternal portion.

Since flexibility must evidently be the end of this great multiplication of the joints, it may perhaps excite surprise that the joints, instead of articulating as in birds by cylindrical surfaces, should have their contiguous faces nearly flat, which must have allowed a less freedom of motion between each vertebra: but it may be answered, that the increased number of the joints compensated for the stiffness of each.

Dorsal Vertebræ.—I have nothing to add to my former remarks on this part of the column: the greater part of these, in the splendid specimen from Lyme,

* Dr. Macartney in his Anatomy of Birds says, "The transverse processes of the vertebræ of the middle of the neck spread forwards, and send down a styloid process of some length."—"The anterior styloid processes are but little observable in the rapacious and passerine tribes, the parrot, &c., but they are very marked in the long-necked birds."

are removed from their place, and are scattered over the mass of shale in which they are imbedded. In consequence of this accident, we are admitted to a full view of the ribs and sterno-costal arcs and pelvis which remain undisturbed. Fourteen large ribs may be counted, and twenty-one dorsal or lumbar vertebræ appear dispersed, though their exact original number cannot be ascertained. The last of these lies over the pubis, and has, close to it, a short false rib.

Twenty-three caudal vertebræ are remaining; and as about 3 of the extreme ones appear to be wanting, we may probably assume this part at about 26 joints, the whole vertebral column then will number about 90 joints, viz. 35 cervical, 6 anterior-dorsal, 21 dorsal and lumbar, 2 sacral, and about 26 caudal. The proportions of the whole of these parts will stand nearly thus: taking the head as 1, the neck will be as 5, the body as 4, and the tail as 3, the total length being, as was before remarked, 13 times that of the head.

The chevron bones beneath the tail are finely exhibited; but this part, having been fully described in my former papers, suggests no new remarks, excepting that its shortness must have prevented its being used, as in fishes, as an instrument of impulsion in a forward direction, and that it was therefore probably employed only as a rudder to steer the animal by horizontal flexure, or by a sudden vertical stroke to elevate or depress it while swimming through the water.

The anterior sternal portion is greatly concealed by the vertebræ and ribs lying over it: these might be carefully removed and replaced, and the structure of this important part ascertained. From several imperfect specimens which I have examined, it appears to have been complicated in its structure, and nearly to have resembled that of the tupinambis.

The posterior part of the sternum consists of a central bony arc, crescent-shaped, and swelling in the middle; to its horns are applied two sterno-costal branches, which appear as usual to have been connected with the extremities of the ribs by cartilages: the nice adaptation of these parts is beautifully displayed in the specimen.

The pelvis is finely displayed, and resembles the usual type of this part in reptiles, of which the turtle perhaps affords the best example for comparison with the fossil: the ilium is reduced to a long and slender bone, which might, if seen detached, be mistaken for the os pubis; that of several species of turtle is exactly similar. The ischium is like that of most reptiles; and the pubis, as is also common in this class, is so greatly dilated as to be liable to be mistaken for the ilium if found separately. All these parts are very nearly *in situ*, and the manner in which they unite to form the acetabular socket is easily perceived; the oval formation between the ischium and pubis is also quite distinct.

Humero-sternal parts.—In one of the specimens of Saurian remains, presented by Colonel Birch to the Museum at Oxford, the humero-sternal, or rather *humero-clavicular,* parts on one side of the animal are almost perfect. It is only at the extremities of the clavicle and scapula that the bones themselves are preserved; but the intermediate parts, though removed, have left an impression of their lower surface. Enough remains to enable us with certainty to identify these bones with more perfect specimens of the same, which have been found in a detached state. It is from these materials that I have effected the restoration of the humero-clavicular parts represented in Plate XLIX. fig. 2.

The humero-clavicular parts consist, as in birds, and as in the lizard and some other reptiles, 1st, of coracoid bones separated from the scapula; 2d, of a small scapula; and 3d, of clavicles.

The coracoid bones in the specimen at Oxford, are greatly elongated in comparison of those represented in my first memoir, though resembling the latter in every other particular. I hesitate to consider this difference as specific; because the shorter coracoids evidently belonged to a much younger individual than the longer, as appears from the circumstance of these and other bones, which have become anchylosed in the latter case, remaining distinct in the former. I ought, however, to add, that a third fragment of this part, which certainly belonged to a large adult, and exhibits the anterior portion of the two coracoids adhering to a series of anterior dorsal vertebræ, agrees in form most nearly with the shorter specimen. The specimen belonging to the Duke of Buckingham possessed the long coracoids, traces of them being very evident beneath all the anterior ribs. Should it appear on further inquiry, that there were two species, we learn from the specimens already procured, that the specific distinctions were very slight, that noticed in the coracoids being in fact the only one that I have been able to detect after a careful collation of the most important parts in all the specimens that I have examined.

The scapula has been correctly represented in my first memoir; but the humerus, which I had there figured from the only specimen in which I had seen those two parts together, and which having belonged to the late Mr. Catcott, is preserved in the public library at Bristol, in consequence of an accidental dislocation, is exhibited in an inverted position. The clavicles consist of two transverse and one central piece. The former are the clavicles, strictly speaking; the latter may perhaps more properly be referred to the sternum. The corresponding part or furcula in the ichthyosaurus also, consists of two transverse and one central piece, as does that of the ornithorynchus, when young, as has been noticed by Mr. Clift; but the central piece in these animals forms merely a short stem or handle (as it may be called) connected with the transverse clavicles; whereas in the plesiosaurus it is considerably more developed. The general analogies between these parts in the reptile tribe, in the ornithorynchus, and in birds, have been ably pointed out by Geoffroy St. Hilaire and Cuvier.

In the plate containing a restoration of the plesiosaurus, I have added for the purpose of comparison a sketch of this part in the ichthyosaurus. That published in the Philosophical Transactions does not exhibit the tripartite division of the furcula, and erroneously makes its branches curve considerably too much upwards. The present outline is founded on three very perfect specimens, which entirely agree with one another in the parts here represented, and leave no doubt of their actual form.

Extremities.—The humerus articulates immediately with the bones which in my preceding descriptions I had considered as the first row of the carpus; which contains only two instead of the three pieces placed together in the conjectural restoration. I have again to acknowledge the error into which I have been led in the insertion of a supposed radius and ulna between these parts; for the two pieces which form the first row formerly ascribed to the carpus, now appear to be the true representatives of the radius and ulna, though greatly differing in form from the usual type of those parts *.

All the paddles are composed of two rows of nearly circular or discoidal bones, representing the carpus and tarsus, and of five digitated series, representing the metacarpal or metatarsal and phalangic bones (the distinction between these being inappreciable, though we may of course in conformity to the usual nomenclature, term the first phalangic bones metacarpal, &c., if so inclined. The first or anterior digit on each paddle has four phalanges; the last seven. These are evidently complete in the specimen; the whole five digits stand as follow:

Anterior paddle.		Posterior paddle.	
1st digit,	4 phalanges.	1st digit,	4 phalanges.
2d	7, and seems complete.	2d	8, complete.
3d	7, incomplete.	3d	10, } uncertain whether
4th	6, incomplete.	4th	9, } complete or not.
5th	7, complete.	5th	7, complete.

This great multiplication of joints in the phalangic series strongly di-

* The conjectural restoration of the paddles would very nearly apply to the posterior paddles as exhibited in this specimen, by abstracting the outer bone from this supposed carpus, and removing also the exterior and circular bones from the edges of the paddle as there drawn. I was led to introduce these exterior paddle-bones from the specimen represented fig. 1, Pl. XLII., Geological Transactions, Vol. V., in which they are so placed; but I have subsequently re-

XXI.—*Notice on the Megalosaurus or great Fossil Lizard of Stonesfield.*

By the Rev. WILLIAM BUCKLAND, F.R.S. F.L.S.

PRESIDENT OF THE GEOLOGICAL SOCIETY, AND PROFESSOR OF MINERALOGY AND GEOLOGY IN THE UNIVERSITY OF OXFORD, ETC.

[Read February 20th, 1824.]

I AM induced to lay before the Geological Society the annexed representations of parts of the skeleton of an enormous fossil animal, found at Stonesfield near Woodstock, about twelve miles to the N. W. of Oxford; in the hope that, imperfect as are the present materials, their communication to the public may induce those who possess other parts of the same reptile, to transmit to the Society such further information as may lead to a more complete elucidation of its osteology.

The specimens here engraved are all preserved in the Oxford Museum. Nothing approaching to an entire skeleton has yet been found, nor have any two bones been discovered in actual apposition, excepting the vertebræ engraved at Pl. XLII., and a similar series of equal magnitude presented to the Geological Society by Henry Warburton, Esq.

The detached bones here represented must have belonged to several individuals of various ages and sizes; there are others in the Oxford Museum which are derived from a very young animal; in the same stratum with them there occur also fragments of large bones, of similar structure, which have been rolled to the state of pebbles. Although the known parts of the skeleton are at present very limited, they are yet sufficient to determine the place of the animal in the zoological system. Whilst the vertebral column and extremities much resemble those of quadrupeds, the teeth show the creature to have been oviparous, and to have belonged to the order of Saurians or Lizards. The largest thigh-bone of this animal in the Museum at Oxford is two feet nine inches long, and nearly ten inches in circumference at its central or smallest part. [See Pl. XLIV. fig. 1 and 2.] From these dimensions as compared with the ordinary standard of the lizard family, a length exceeding 40 feet and a bulk equal to that of an elephant seven feet high have been assigned by Cuvier to the individual to which this bone belonged; and although we cannot safely attribute exactly the same proportions to recent and extinct species, yet we may with certainty ascribe to it a magnitude very far exceeding that of any living lacerta. Large as are the proportions of this individual, they fall very short of those which we cannot but deduce from a thigh-bone of another of the same species, which has been discovered in the ferruginous sandstone of Tilgate Forest near Cuckfield, in Sussex, and is preserved in the valuable collection of Gideon Mantell, Esq. of Lewes, together with many other bones belonging to the same species, and of the same size with those from Stonesfield.

*The femur in question, which has lost its head and lower extremity, measures in its smallest part, at the distance of two feet from the upper extremity, more than twenty inches in circumference, and therefore, when entire, must have equalled in magnitude the femur of the largest living elephant.

To judge from the dimensions of this thigh-bone, its former possessor must have been twice as great as that to which the similar bone in the Oxford Museum belonged; and if the total length and height of animals were in proportion to the linear dimensions of their extremities, the beast in question would have equalled in height our largest elephants, and in length fallen but little short of the largest whales; but as the longitudinal growth of animals is not in so high a ratio, after making some deduction, we may calculate the length of this reptile from Cuckfield at from sixty to seventy feet. In consideration therefore of the enormous magnitude which this saurian attains, I have ventured, in concurrence with my friend and fellow-labourer, the Rev. W. Conybeare, to assign to it the name of *Megalosaurus*.

The other animals that are found at Stonesfield are not less extraordinary than the megalosaurus itself. Among the most remarkable are two portions of the jaw of the didelphys or opossum, being of the size of a small kangaroo rat; and belonging to a family which now exists chiefly in America, Southern Asia, and New Holland. I refer the fossil in question to this family on the authority of M. Cuvier, who has examined it; and without the highest sanction, I should have hesitated to announce such a fact, as it forms a case hitherto unique in the discoveries of geology; viz. that of the remains of a land quadruped being found in a formation subjacent to chalk.

* Mr. Mantell in his Geology of Sussex, p. 53, speaking of this bone and others in his collection, says, "Some fragments of a cylindrical bone, probably the femur, indicate an animal of gigantic magnitude. I have specimens from ten to twenty-seven inches long, and from eleven to twenty-five inches in circumference, the substance of the bone being more than two inches thick. Some examples have large *foramina* for the passage of blood vessels."

The bones of long-legged birds, apparently allied to the order Grallæ, which frequent the shores and shallow fords of seas or lakes, are found also imbedded in the same stratum, and afford, I believe, the most ancient example yet discovered of the occurrence of fossil birds, which, like the terrestrial quadrupeds, have hitherto (with one exception mentioned in the sequel) been noticed only in strata above the chalk.

The elytrons also (or exterior sheath of the wings) of more than one species of beetle occur in the same slate, and, excepting in this instance and in the shale of the Danby coal-pits of the oolite formation in Yorkshire, (see page 2 of Contents of the Geological Survey of the eastern Part of Yorkshire, by Messrs. Bird and Young,) have not hitherto been discovered, I believe, in any stratum below the chalk.

The megalosaurus itself was probably an amphibious animal, and we might therefore expect (as is actually the case) to find it associated with the remains of other amphibia, e. g. the scales and teeth of crocodiles and scales of tortoises. There are also teeth which appear to belong to the plesiosaurus.

The remains of land animals and amphibia are small in number, however, in comparison of the marine exuviæ with which this stratum is crowded; besides an immense number of species of shells decidedly marine, e. g. nautili, ammonites, trigoniæ, and belemnites, there occur abundantly the teeth of sharks, and the teeth, palates, scales, spines, and bones of many unknown species of fish, together with the remains of two or three species of small crustaceous animals of the crab and lobster kind. In the nearly adjacent quarries of cornbrash limestone, at a place called Gibraltar, near Enslow Bridge on the east of Woodstock, the bones of large cetaceous animals are accompanied by the scales, teeth, and bones of a species of crocodile nearly resembling the modern gavial or crocodile of the Ganges, and by numerous marine shells. This cornbrash is the same with that which at Stonesfield is immediately incumbent on the bed that is worked for slate.

Of the vegetable kingdom also, the remains which occur at Stonesfield are very numerous, and present a no less curious assemblage of genera than the animals. We find an abundance of plants decidedly terrestrial, e. g. fragments of trees and ferns; several species of seeds and fruits; and branches and leaves which nearly resemble the Thuia and the ginger plant of modern botany. There are others, apparently lacustrine or fluviatile, e. g. gigantic reeds and grasses; and others again decidedly marine, e. g. algæ, fuci, &c. All these vegetable fragments are dispersed in the same irregular manner, and are mixed up with the wreck of the marine, amphibious, and terrestrial animals above enumerated.

The whole of these remains are found in a bed of calcareous, sandy slate, the greatest thickness of which does not exceed 6 feet, and which lies in the upper part of the third, or lowest division of the oolitic rocks; being nearly connected with the forest marble, and interposed between the superstratum of cornbrash and substratum of the great oolite of Bath. Its place among the continental equivalent formations, is between the central and lowest strata of the Jura limestone.

In working the quarries at Stonesfield, they descend by vertical shafts through a solid rock of cornbrash and stratified clay, more than 40 feet thick, to the slaty stratum containing these remains: it is important to notice this circumstance, because it has been supposed by many persons who have never visited the quarries, that the remains are lodged either in fissures and cavities, or in a superficial and merely local deposit. This is decidedly not the case. They are absolutely imbedded in a deeply-situated regular stratum of the rock itself, which is known to extend across England, from Coly-Weston near Stamford in Lincolnshire, to Hinton near Bath, and is in many places extensively quarried for coarse oolitic slate used for covering houses. Many of these quarries abound in marine and vegetable remains; but the megalosaurus, opossum, birds, and coleopterous insects, have, I believe, as yet been observed in it only at Stonesfield.

Mr. Mantell possesses, in his rich and highly valuable collection at Lewes, a small vertebra of megalosaurus, which he purchased in London, having a label on it denoting that it came from Bath; its matrix appears to be the Bath oolite. In the Oxford Museum there is a rib of this animal, labelled Stonesfield, and imbedded also in a mass of Bath oolite or cornbrash. The cornbrash and Bath oolite are the beds, the former immediately above, the latter immediately below, the Stonesfield slate. As the megalosaurus occurs also in the ferruginous sand of Tilgate Forest, it is clear that the range of this animal extends downwards from this formation to the Bath oolite, and it is probable that its bones will hereafter be found in all the intermediate formations. It has never yet been noticed in chalk. It is totally distinct from the gigantic monitor of Maestricht, of which Mr. Mantell has also discovered some vertebræ in the chalk near Lewes, and at Steyning, being, I believe, the only traces of this animal yet noticed in England.

It appears from the collection of Mr. Mantell, that the bones of megalosaurus are not less abundant in the ferruginous sand near Cuckfield in Sussex, than they are in the oolitic slate near Oxford. He has numerous bones of many individuals of various sizes and ages; most of them broken, and some rolled, as at Stonesfield, to the state of pebbles. He has also many small teeth of this animal.

In the same quarries at Cuckfield, he has discovered also the remains of birds, being, with the exception of Stonesfield, the only instance of the kind that I know of in strata beneath the chalk.

He has also established many other remarkable analogies between the animal remains of the Tilgate Forest beds, and those of Stonesfield, which may be most briefly stated in the subjoined tabular form:

Fossil Remains of Stonefield Slate.	Fossil Remains of Iron Sand of Tilgate Forest.
Birds.	Birds.
Megalosaurus.	Megalosaurus.
Plesiosaurus.	Plesiosaurus.
Crocodile scales, teeth, and bones.	Crocodile scales, teeth, and bones.
Whale, humerus and ribs.	Whale, humerus, ribs, and vertebræ.
Tortoise scales.	Tortoise scales and bones.
Sharks' teeth, many varieties with striated surfaces, all differing from those in chalk, of which the surfaces are smooth.	Sharks' teeth, many varieties with striated surfaces, all differing from those in chalk, of which the surfaces are smooth.
Spines of balistes.	Spines of balistes.
Palates of sea wolf and other fishes.	Palates of sea wolf and other fishes.
Scales, teeth and bones of fishes.	Scales, teeth and bones of fishes.
Fossil wood.	Fossil wood.
Ferns and reeds.	Ferns and reeds.
Small leaves converted to coal.	Small leaves converted to coal.
Quartz pebbles, rarely.	Quartz pebbles, rarely.

The above analogies are very striking; and though they show that the condition of the earth was nearly the same at the time when both these formations were deposited, yet the numerous and thick strata of oolite interposed between the two, forbid us, even for a moment, to suspect their identity. The same conclusion also follows from a considerable variation between their fossil plants, and from an almost total discrepancy between their fossil shells.

In a future communication, I propose to give a description with plates of the other most remarkable remains that occur at Stonesfield. My present object is to confine myself to the megalosaurus; and as we are yet in possession only of dislocated fragments of this animal, the best method I can adopt is to subjoin the following description, imperfect as it is, of the plates annexed to this notice.

Head.—No part of the head of the megalosaurus has yet been discovered, excepting many single teeth and a fragment of the lower jaw. See Plates XL. and XLI.

Mode of Dentition: see Plates XL and XLI., figs. 1, 2.—The teeth are lodged in distinct alveoli, but do not adhere, as in the monitors, by any incorporation of the root or sides with the substance of the jaw; the young teeth are hollow at the base, and, as usual, become filled as they grow older.

The new teeth are formed in distinct cavities by the side of the old ones towards the interior surface of the jaw, and probably expel the old teeth by the usual process of pressure and absorption, and insinuate themselves into the cavities thus left vacant. The teeth are flattened laterally, and recurved backwards, being serrated on the posterior edge along the whole extent of their enamel, and also on the anterior edge when young; this edge is thicker, and, like the back of a knife, is more solid than the posterior or cutting edge.

The outer rim of the jaw rises almost an inch above the inner rim, and forms a continuous lateral parapet supporting the teeth externally; whilst the inner rim throws up a series of triangular plates of bone forming a zigzag buttress along the interior of the alveoli. From the centre of each triangular plate, a bony septum crosses to the outer parapet, thus completing the alveolus.

The new teeth rise in the angle between each triangular plate. The exterior surface of the jaw (Plate XLI. fig. 2.) presents several distinct and rugose cavities for the passage of the exterior branches of the inferior maxillary blood-vessels and nerves. This character agrees, not with the crocodiles, but with the other members of the saurian family.

From the absence of any curvature in this fragment of the anterior extremity, (which is nearly one foot in length,) it is obvious that the lower jaw must have terminated in a flat, straight, and very narrow snout.

The exuberant provision in this animal for a rapid succession of young teeth, to supply the place of those which might be shed or broken, is very remarkable; it seems also, that a small number of teeth only were in use at the same time.

Vertebræ.—The bones that we have as yet discovered of the vertebral column, are confined to five anchylosed joints, including the two sacral, and two others which are probably referable to the lumbar and caudal vertebræ. They are all much contracted in the middle, and have a deep fossa immediately beneath the annular part. See Plate XLII.

Although we are without any dorsal vertebræ, we fortunately possess ribs (see Plate XLIII. figs. 1. 2.) which have a double articulation at their head, as in the crocodile.

The articulating faces of the body of the vertebræ are nearly flat surfaces, as in most of the fossil crocodiles, and in the plesiosaurus; their proportions will be at once seen by reference to the Plate XLII., in which fig. 1. represents a portion near the sacrum, figs. 2. and 3. the supposed lumbar and caudal vertebræ.

Ribs and supposed Parts of the Pelvis.—Both of the ribs figured at Plate XLIII. figs. 1. and 2. have a double articulation with their respective vertebræ; the smaller one, fig. 2., is apparently one of the anterior false ribs; two transverse sections of the larger one at *a*. and *b*. show its proportions at the points of fracture.

The bone represented in fig. 3. is the outside view of the ilium, slightly concave. The inner surface is slightly convex, and shows marks of its articulation with the sacrum.

With regard to the os pubis, I am inclined to consider the specimen fig. 4. as forming this bone, but speak with hesitation, as it may be the coracoid process of the scapula: fig. 5. appears to be the ischium; it is very strong and solid, being nearly three inches thick throughout: fig. 6. appears to be a fragment of a scapula; it is from an inch and a half to two inches thick.

Extremities.—These will best be understood by reference to Plate. XLIV. in which figs. 3. and 4. are two views of the same bone, apparently a clavicle; figs. 1. and 2. are two opposite views of the same bone, viz. the largest femur I have from Stonesfield. The medullary cavity of this bone is very large, and is frequently filled with a mass of white calcareous spar; the substance of the bone is extremely compact and brittle. Fig. 5. is apparently a fibula; and fig. 6. a portion of a large bone of the metatarsus or metacarpus.

XXII.—*On the Geology and Topography of the Island of Sumatra, and some of the adjacent Islands.*

BY THE LATE WILLIAM JACK, M.D. M.G.S.

[Read April 18th, 1823.]

THE various journeys which have recently been made into the interior of Sumatra, have considerably extended our hitherto very imperfect knowledge of the geography of that island, and have also furnished materials for a slight outline of its geological structure. Some account of the information which has been acquired on both these topics, may not prove unacceptable as an accompaniment to a small collection of specimens of the rocks of that country, which I have transmitted to the Geological Society.

I obtained these chiefly from the western coast of the island, which, from its greater boldness and proximity to the mountains, is the most accessible to mineralogical investigation. It is to the eastern side that all the great rivers take their course, where the extent of alluvial land is consequently much the most considerable. If any reliance can be placed on native traditions, the increase of surface on this side, by alluvial deposit, has been great and rapid; as in all their earliest histories the town of Palembang, which is now at least sixty miles from the mouth of the river, is mentioned as a sea port; and the adjacent hill of Siguntangguntong as an island. The smoothness of the inland seas, into which these rivers flow, must certainly favour the accumulation of the earthy particles which they wash down.

On the western side, a difference of character and aspect may be remarked between that portion of the island which lies to the north of Indrapore and the southern. The former comprises about two thirds of the length of the island, and includes the richest and most interesting districts; its coast is more irregular and broken, and is defended by innumerable small islands; while the hills, at one time approaching towards the shore, at another receding from it, appear to pursue no determinate line. In the southern portion, the coast is but slightly indented, and is skirted by few islands; while the hills run in nearly a continuous chain, as far at least as Bukit Pugong near Croee, at a distance of from ten to twenty miles from the coast, and form what is usually called the Bukit Barisin or Barrier range. In the northern portion, there is much less appearance of parallelism in the distribution of the hills; and though the whole of Sumatra may, in a general view, be considered as forming a great chain parallel to that of the Malayan peninsula, its parts by no means exhibit a corresponding regularity. In this particular the greater number of maps convey an erroneous idea.

It has been ascertained, that the Poggy islands, Pulo Nias, and the whole of the northern coast, are laid down in Horsburg's charts considerably to the westward of their true position: a circumstance which materially affects the supposed breadth and form of the island; and it is singular that, with the exception of Acheen Head, Bencoolen, and perhaps Flat Point, there is scarcely a place on the west coast (where we have had establishments for above a century) of which either the latitude or longitude is exactly determined. The mountains, for the most part, lie nearer to the western coast than might be supposed from Marsden's map; and a greater length of course must, therefore, be given to the great eastern rivers, which have their sources among them. It has been an object of interest in our late investigations to trace more correctly the course, the relative position, and true sources of these noble streams, most of which afford safe navigation to the largest vessels for upwards of a hundred miles above their mouths.

The basis of the island of Sumatra is probably primitive; granite has been found in Menang kabau and at Ayer Bangy: but trap rocks are perhaps the most widely diffused; while the mountains of greatest elevation, and which stand in some degree insulated, are generally volcanic. The volcanoes of Sumatra have somewhat a different character from those of Java: the former generally terminating at the summit in a ridge or crest; while the latter are more exactly conical, and have for the most part much broader bases.

Commencing at the north with Acheen [respecting which the mission of Sir T. S. Raffles in 1819 afforded the means of adding to our information] I have merely to remark, that the mountains which terminate in Acheen Head, together with the adjacent island of Pulo Way, and the coast to the eastward including Pedier, are of calcareous formation.

Proceeding southwards along the western coast, we come to the Bay of Tappanooly, which forms a large and deep indentation among the hills of the Batta country. In these hills, which come directly down to the margin of the sea, as well as in the small islands within the circumference of the bay, the rocks consist chiefly of a fine-grained sandstone, frequently striped with various shades of yellow and red. The strata are in general even and regular, and but slightly inclined, occasionally, however, exhibiting partial disturbances and undulations.

At Nattal, the next station to the southward, the mountains recede to some distance from the coast, leaving a portion of level land, through which the river pursues a winding course to the sea. There is a small detached hill near its mouth entirely composed of limestone, of which a great quantity in loose blocks and fragments is strewed at the bottom. The soft argillaceous iron ore, commonly called ruddle, has also been procured from the upper part of the river.

Inland of Tappanooly and Nattal, lies the country of the Battas, in which the position of the great lake of Tobah, not laid down in our maps, has lately been determined. It lies about fifty miles north-east of Tappanooly.

The Batang Tava and Sinkuang have been represented as inconsiderable streams, while they are in fact among the largest rivers on the western coast; the former having its source in the mountains of Diri, to the north of Tappanooly, and the latter rising in Gunong Kalaber, the southern boundary of the Batta country, and watering in its source the whole province of Mendheling. The Tabuyong on the other hand, which is represented by Mr. Marsden as the largest river between Tappanooly and Nattal, is in fact small, and does not penetrate beyond the first range of hills.

The province of Mendheling, which lies inland of Nattal, has long been celebrated for its gold, which is of the finest quality. It is said to possess upwards of seven hundred mines, and its annual export of gold probably does not fall short of a thousand tales.

At Ayer Bangy, where the hills again approach the sea, granite makes its appearance. This place lies nearly due east from Gunong Pasaman (known in our charts by the name of Mount Ophir), a remarkable conical mountain, whose height was some years ago estimated at 13,800 feet above the level of the sea, its latitude at 6′ north, and its distance from the coast about 26 miles. On its north-eastern side is the source of the great river of the Soompoor or Rukan, which crosses the island in a north-easterly direction, passing through the fertile valley of Rau, at its exit from whence it bursts through the range of mountains forming the eastern boundary of that country; and after precipitating itself over a considerable fall, enters the district of Rukan, from which it receives its name in this part of its course.

To the southward of Rau lie the provinces of Agam, Rana-lima-pulo, and Menangkabau, which, collectively distinguished by the appellation of the "Darat," or "the Land," constituted the ancient empire of Menangkabau. In the territory which was formerly included in that empire, the population is at present estimated at not less than a million and a half; and some of the villages or towns are several miles in circumference. The Siak river, which is navigable for a hundred miles from its mouth, rises in the northern portion of Rana-lima-pulo, and chiefly from the mountain Tinkalang.

With Menangkabau and the sources of the Indragiri river, the journey undertaken in 1818 by Sir T. S. Raffles has made us better acquainted. He proceeded from Padang, on the west coast, and after crossing three ridges of hills, exceeding 4000 feet in height, and covered with primeval forests, through which the beds of torrents afforded the only passage, he descended upon the Tigablas country, which is bounded on the south by Gunong Tallang. The cultivated part of the great valley of Tigablas may be about twenty miles long and ten broad, and would seem to have been at one time entirely covered by the waters of the existing lake, which is skirted by hills in every direction, that of the valley excepted. Gunong Tallang, with its adjacent hills, seems to form a transverse range, and to break the regularity of all the other ranges which it intersects. On the eastern side of the lake, which is about fifteen miles long by from seven to nine broad, commences the province of Menangkabau Proper, and at the distance of a few miles from its banks is situated the ancient capital of Pagaruyong.

The Indragiri river has its source on the eastern side of lake Sophia*, and flows through the province of Menangkabau, receiving the waters of the celebrated Ayer Mas or "Golden Stream," which passes through Pagaruyong, and soon after of a large river which rises in Agam, behind G. Singalang and G. Berapi, and traverses a portion of the more eastern district of Rana-lima-pulo. The Indragiri is navigable for small boats a considerable way above the falls; but the exact position of these has not been ascertained. The mountain of most interest in this quarter is that of Berapi, which is constantly emitting smoke: its elevation was ascertained, by angles taken from the lake, to be about 13,000 feet; it is connected towards the western coast with the mountain Singalang, estimated at about 12,000 feet; and to the north and eastward with Gunong Kasumbra, first discovered on this expedition and calculated to be not less than 15,000 feet above the level of the sea; being therefore the highest mountain in Sumatra. The Kampar, which is mentioned in the Portuguese histories as of some importance, is a river of small size, situated between the Siak and Indragiri; it has its origin in the easternmost hills, which bound the province of Rana-lima-pulo, and does not penetrate beyond them into the more elevated country of the "Darat."

As a detailed account of the journey to Menangkabau, and of the observa-

* The lake, to which the natives had given no proper name, has lately received the denomination of Lake Sophia, in honour of Lady Raffles, who accompanied Sir T. S. Raffles in his late expedition into this part of Sumatra.

tions made during the course of it, will probably be given by Dr. Horsfield, who accompanied Sir T. S. Raffles on that occasion, I shall here only remark generally, that granite was observed on both sides of the lake; sometimes passing into gneiss and micaceous schistus, and at others associated with marble and limestone, or with sandstone; that basaltic and trap rocks were abundant; and that obsidian, lava, and pumice were observed in the valley of the Tigablas.

The country to the southward of Padang, as far nearly as Indrapore, is a confused assemblage of hills, which come directly down to the sea; and the whole coast is broken into innumerable bays and islands. Through the greater part of these, the mountain masses of rock are composed of a kind of trap or amygdaloid, containing, in a cement of a grayish-brown colour, numerous small fragments or nodules of other rocks, so firmly united, that the fracture takes place through both indiscriminately, and so hard as often to ring under the hammer. Padang head is chiefly composed of trap; it also furnishes pebbles of chalcedony and large crystals of quartz.

From Indrapore to Bencoolen, the range of hills runs nearly parallel to the coast, leaving a belt of lower, but not level land between them and the sea, whose action has exposed a long range of cliffs composed of a stiff dark red clay. Behind the first range of hills to the east of Moco Moco, lies the country of Korinchi, in which there is a considerable lake, which was first visited by Dr. Campbell in 1800, and by him named Lake George. It was again visited by the directions of Sir T. S. Raffles in 1818, and the party proceeded as far as Penkalan Iambi. From the observations then made, it appears that the lake is much nearer the western coast, and more to the southward than is laid down by Marsden; and that a cultivated valley lies to the north of it, watered by a small river, which descends to the lake from Gunong Api, a high volcanic mountain constantly smoking, and distant about sixty miles north-east of Indrapore point. The small lake noticed by Marsden, which should also have been placed to the northward, was dried up about ten years since by the effect of an earthquake. Lake George gives out a considerable stream at its southern end, which passing through the district of Penkalan Iambi, becomes one of the principal branches of the river Iambi.

The countries of Limun and Batang Assii, through which the two southernmost branches of this river pass, abound in gold, which has latterly been chiefly exported to Moco Moco, Bencoolen, and Palembang.

At Bencoolen the line of hills is situated about twenty miles inland; and the space between them and the sea exhibits a succession of ridges and ravines, whose general direction is parallel to the coast, though frequently altered and broken by the irregular working of springs and streams. The hills are principally of the trap formation, and exhibit several varieties of basalt, whinstone, and much of the same gray amygdaloidal trap observed in the neighbourhood of Padang. The most remarkable hill in this quarter is detached from the Barrier range, and is called Gunong Bungko, or by Europeans the Sugar-loaf. I had lately an opportunity of ascending it, and found it composed almost entirely of irregular masses of basalt or trap, whose bare surfaces are frequently exposed, rising from amid the luxuriant vegetation of the declivities. It had not previously been explored, the shape of the hill rendering the ascent extremely difficult. Its elevation is less than 4000 feet; yet towards the top the trees became stunted, the rocks were clothed with dense moss, and the vegetation assumed a character decidedly Alpine. In the beds of some of the rivers near Bencoolen, particularly that of Silebar, are found pebbles of jasper and chalcedony, with nodules of indurated clay. Iron ores occur not unfrequently, and in one part of the Bencoolen river a bed of coal is laid bare by the stream. Very fine specimens of siliceous petrified wood have also been found in the hills of the interior.

It was not till 1818 that a journey was accomplished across the island of Sumatra in any part. In that year, a party proceeded from Bencoolen to Palembang; and the facilities of communication are now found to be such that, did not political obstacles intervene, it would no doubt soon become a frequent channel of intercourse between Bencoolen and the more eastern parts of the Archipelago.

The Pasummah country, which was first visited by Sir T. S. Raffles in 1818, is an extensive plain of remarkable fertility, considerably elevated above the sea, as may be inferred from the temperature, the thermometer being usually as low as 65° at 10 A. M. From this plain rises Gunong Dempo, which towers above all the mountains of this part of Sumatra, and is estimated to be no less than 12,000 feet above the level of the sea. It is almost constantly emitting smoke; and hot springs and other volcanic phænomena are common in its neighbourhood. It has been ascended since Sir T. S. Raffles's visit; vegetation was found almost to cease near the summit, and a large portion of it bore evident marks of a late and violent eruption. The cold was extreme, and the ascent difficult; but, owing to a mistake of the guides, the party did not reach the present crater. The hills which separate Pasummah from Mannæ, and indeed the whole barrier range from Bencoolen to Cawoor, are composed of basalt or trap: from the plain of Pasummah I have specimens of quartz abounding with masses of iron pyrites.

In the interior of the Lampong country is a lake, the position of which was not sufficiently determined to enable Mr. Marsden to lay it down in his map. This lake has been twice visited within the two last years by the orders of Sir T. S. Raffles : from its neighbourhood are obtained jasper, slate rock, and trap; there is a hot spring on one side of it. It gives origin, near its southern extremity, to a river which, after passing through the country of Haji, takes the name of Kamring, and falls into the Palembang river a little below the town.

Tulang Bawang rises in Gunong Ompo, to the southward of lake Ranau, and has no communication, as was formerly supposed, with the Palembang.

Among the islands which skirt the western coast of Sumatra, the largest and most important is that of Pulo Nias; which has hitherto remained almost unknown to Europeans. It is about seventy miles long by twenty-five broad, and is for the most part hilly, though none of its mountains are of great elevation. It is very populous, and its soil, which is naturally rich, is highly cultivated. The most singular circumstance in its geological structure, is the extensive occurrence of calcareous masses of coral origin, which are found near the surface on almost all the hills, lying immediately above the rocky strata, and to all appearance precisely in their original position *. These coral masses are in general so little altered that their different species can be determined with certainty, and even the fragile stems of the Madrepora muricata, and other branched kinds, may be found no otherwise injured than by the

* The specimens of coral which were received from Pulo Nias, and which were collected from the hills by Dr. Jack, as appears from the labels attached to them, are all rounded masses, evidently water-worn, and they may be divided into two classes. The 1st appears indeed exactly to resemble recent coral ; the structure of the coral is unaltered, and the cells of the polypes empty, and consequently the rock is of the usual lightness of coral. The 2d class consists of a calcareous rock of the ordinary specific gravity of limestone : in specimens Nos. 19,105 and 19,106 the rock resembles some of the oolitic beds of Europe, and there are dispersed through it faint traces of coralline bodies, which probably indicate that it has been originally derived from corals; but in general the substance of the coral has been almost entirely dissolved, and the pores of what remains filled up by sparry matter. This specimen has the aspect of an ancient rock. Another specimen, No. 19,104, exhibits very faint traces of coralline bodies ; but the rock is filled with innumerable irregular cavities, which are stained internally by oxide of iron : the specific gravity of this last is also that usual to limestone. The rounded shape of the specimens, Nos. 19,104, 19,105, 19,106, leads us to infer, that they were not procured from a rock *in situ*, but were perhaps found lying on the surface, or imbedded in the soil of the hills : if so, they may be considered as detritus ; and may therefore very possibly be portions of solid strata existing in the island. The specimen of recent coral, stated to be found in the hills, is water-worn, and appears to have been a detached piece.—*Note by the Secretaries.*

pressure of the superincumbent soil, and the constant infiltration of water through it. The species are obviously the same with those which now abound under the neighbouring sea, and sometimes the transition from the recent to the fossil coral is only effected by the gradual rise of the land from the shore. Large Kima shells (Chama Gigas) are also found on the hills, exactly as they occur on the present reefs, and are collected by the inhabitants for the purpose of cutting into rings for the arms and wrists. Every thing seems to indicate that the surface of the island must at one time have been the bed of the ocean, and that, by whatever means it attained its present elevation, the transition must have been effected with little violence or disturbance to the marine productions at the surface. The subjacent rocks are stratified; among them I found granular quartz, limestone, and calcareous sandstone*; towards the southern end I also met with several kinds of limestone, some a coarse yellowish white stone, and others of a blueish cast, with small fragments of shells intermixed.

At one place at Tallo Dalam, I found strata of a calcareous rock, laid completely bare, on the crest of a hill, dipping to the north-east, with an inclination of above 45°, and abruptly broken on the other side into a kind of stair. I have a specimen of this rock†, which contains fragments of shells and fossil wood.

The appearance of unchanged and unfossilized masses of coral on the surface of the hills, seems most readily explicable on the supposition, either of a subsidence of the ocean below its original level, or a heaving up of the island by a force from beneath. If we admit the former of these causes, indications of a similar subsidence ought to be found on the adjacent coasts: but I am not aware of any such having been observed. The great inclination of the strata, and the dislocation they sometimes appear to have suffered, would seem to favour the latter hypothesis. It must still however be regarded as a phenomenon of a most singular kind, that so large an island, diversified with numerous hills from 800 to 3000 feet in height, should have been heaved up from the sea with so little disturbance to the fragile marine productions on the surface.

* It is highly deserving observation, that these rocks, particularly No. 19,099, have a striking resemblance to parts of the green sand formation in England, especially to the rock called Kentish rag; and it is also worthy of remark, that in Sumatra, on the part opposite to Pulo Nias, at Nattal-hill, a rock occurs, exactly corresponding to No. 19,099: this bed, therefore, probably extends across the channel that separates Pulo Nias from Sumatra.—*Note by the Secretaries.*

† This specimen, No. 19,103, is probably from one of the lower beds of the island; it bears a considerable resemblance in its aspect to one of the rocks of the oolitic series.

The appearance and nature of these productions would indicate a comparatively recent date to the event.

The other large islands of the chain, Pulo Batu, Mantawi, and the Poggies, are less known, but are probably not very dissimilar in structure to Pulo Nias: they are not nearly so populous or so well cultivated; but the quantity of sago and cocoa-nuts which they produce, sufficiently proves that they are not deficient in fertility and natural resources.

The islands on the eastern side of Sumatra are of two descriptions: those which lie off the mouths of the Siak and Indragiri rivers, on the western side of the Straits of Malacca, are merely alluvial flats; while the islands of Banca, Lingen, &c., may more properly be considered as belonging to the Malayan chain, and as a continuation of the range which forms the peninsula of Malacca; being similar to it in geological situation, and in their mineral products, the most abundant and remarkable of which is tin.*

* In the collection of rocks sent by Dr. Jack from Sumatra occurs a specimen, No. 19,345, of soft white chalk, *Creta scriptoria*, containing the fragment of an echinus. No mention of it is made in the memoir, nor was any information contained in the label attached to it, except the locality, Bencoolen.—*Note by the Secretaries.*

XXIII.—*Geological Observations made on a Voyage from Bengal to Siam and Cochin China. Extracted from a Letter to H. T. Colebrooke, Esq. M.G.S.*

By J. CRAWFORD, Esq. M.G.S.

[Read December 5th, 1823.]

We left Calcutta in the end of November 1821, and proceeded down the Bay of Bengal and the Straits of Malacca to Singapore. We then stood across to the coast of the island of Borneo, and from thence to the point of Kumboja. From this place, until we made the river of Siam, we passed through the innumerable and almost unknown clusters of islands which skirt the east coast of the Siamese Gulf. We continued at Siam four months, and left it in July 1822. From thence, passing down the Gulf of Siam, we proceeded to Cochin China. Having reached the Bay of Turon, we visited Hué, the capital of Cochin China; thence we returned by land to Turon, a distance of 60 or 70 miles, and finally quitted Cochin China in October 1822.

During this voyage I had an opportunity of forming a small collection of specimens, and making some observations which may, I hope, contribute to throw light on the geology of several of the places which we visited.

The Seyer Islands in the Bay of Bengal, as also the opposite coast of Tannasserim in such parts as fell under my examination, consist of granite, containing in it beds of porphyritic greenstone. The same primary formation continues to Junk Ceylon, Prince of Wales's Island, and the islets around it, down to Dinding in the Straits of Malacca. Cape Rachado, a hilly promontory nearly half way down the straits, we found to consist of quartz. The foundation, at and about the town of Malacca, is cellular clay iron ore; but the mountains of the interior are of granite. The Carimon Islands in the Straits of Malacca are formed of compact felspar; limestone also occurs in them.

At Singapore, a secondary formation is discoverable, and varieties of sandstone and shale form the principal rocks, together with conglomerate argillaceous sandstone, and gray limestone.

The great chain of primitive mountains which stretches along the length of the Malayan peninsula, ceases 30 or 40 miles before reaching its extreme point. This point, in the parts which I have examined, consists of felspar porphyry. Of the Malayan peninsula, I may further observe that on the west coast tin is found, all the way from Tavoy in about the latitude of 14° down to Malacca in 1°; while on the east coast it seems to prevail only as far north as 12° 30′. On the east coast, however, gold is very generally disseminated, but it is not found on the west coast. The most productive tin mines are those of Junk Ceylon, and the richest gold mines those of Pahang and Tringanu.

Although we coasted close to the great island of Borneo, and had a clear view of its stupendous mountains, we had no opportunity of touching any where upon it.

The first spot we visited after leaving the Straits of Malacca was Pulo Abi, an island off the point of Kamboja. This is one mass of granite, and 1600 or 1800 feet high; while the main land, which is opposite to it, consists of an alluvial tract, so remarkably low, that at the distance of five miles no beach is visible, and nothing is seen but the trees.

On our way up the Gulf of Siam, we touched at two small islands in about the latitude of 10° 16′: upon a large island not named in modern charts, but called Quadrol in some old ones, we found the foundation to consist of red sandstone. Here the low alluvial coast of the main land ceased; and from thence the country, as far as the alluvial tract of the Menam, or river of Siam, continued mountainous.

In the latitude of 12° 38′, I landed on a small island close to the coast of Siam. This I found to be composed of a large-grained granite, and of white quartz rock, with flint and gneiss as incidental materials. We touched for the last time before reaching Siam, at Cape Liant, which is laid down in the marine charts. This, and the islands which lie off it, we found to be composed of sandstone.

At Siam itself, situated in the midst of a rich and wide alluvial plain, we had an opportunity of examining the structure of the mountains. The nearest hills to the north, distant about 100 miles, are calcareous, and furnish the capital with the limestone, from which lime is manufactured for architectural purposes. The mountains of Chantibun, on the east coast of the gulf, in the latitude of 12°, afford the precious sapphire, red and blue, but not valuable. Copper, gold, and iron, are found in the mountains to the north-west of the great river, and the latter in such abundance and cheapness, that both in its wrought and unwrought state, it furnishes the neighbouring nations with their chief supply.

A group of small islands about 30 miles from the mouth of the Menam, called Sichang, and in older times the Dutch islands, consist principally of granular limestone. On our return down the Gulf of Siam, we touched at

Pulo Panjang, nearly midway between the two shores. This group is composed of sandstone, among which we found occasional veins of common jasper.

Proceeding on our voyage to Cochin China, we touched at Pulo Condore. This group seems entirely to consist of primitive rocks, chiefly granite and felspar porphyry, both of singular hardness. On the continent of Cochin China itself, Cape St. James, in latitude 10° 10′, is the commencement of a continuous chain of primitive mountains, which stretches to the north until it is interrupted by the alluvial plain of the great river of Tonquin in 20° 40′ north. To the west of it again, is the alluvial tract of the great river of Kamboja; and not a mountain or even hill is to be seen here as far as the latitude 11°. The hills of Cape St. James are about 300 feet high, and composed of granite and porphyry remarkably tough. The first part of this great chain of mountains (portions of which ascend to the height of 6000 feet), that we had an opportunity of investigating, were the hills in the vicinity of the magnificent Bay of Turon. These in their foundation are granite. Our journey over land from Hue, the capital, to Turon, which was fifty miles in length, afforded us the best opportunity of examining the great northern range. Some of the lowest parts of it, near the capital, in latitude about 17° north, consisted of quartz, but the higher parts, of granite and its various varieties. After my return to the Bay of Turon, I made an excursion to the city of Tyfo, about 40 miles distant, and situated near the sea. On my route I met with a remarkable range of marble rocks*, rising almost perpendicularly from the low sand hills to a height of from 300 to 400 feet, without a hill or mountain within 20 miles of them. This marble is to a limited extent quarried for economical purposes.

* These rocks abound in splendid caves containing temples and images in honour of Buddha, although his worship is not now the common religion of the Cochin Chinese.

XXIV.—*Notes made in the course of a Voyage from Bombay to Bushire in the Persian Gulf: transmitted, with a Series of illustrative Specimens,*

By JAMES FRASER, Esq. M.G.S.

[Read November 15th, 1822.]

AFTER a tedious voyage I arrived, on the 4th July 1821, off Rausul-heed, which in Arabic signifies the land's end. From this promontory, situate at the south-eastern extremity of Arabia, the coast as you advance northwards (and I believe westwards also) presents a succession of precipitous and often overhanging cliffs, seldom less than 100 feet high. If a sandy beach occurs beneath, it is generally narrow and of inconsiderable length.

From Rausul-heed to Muscat the vessel was always in sight of the coast, the characteristic feature of which is extreme barrenness. Not a blade of grass could be discovered, nor any sign either of vegetable or animal life.

The sea-cliffs are backed by a range of mountains, which sometimes retire to a considerable distance inland, sometimes approach the shore. Their height is very variable, but at Cape Coriatte it cannot be less than 3000 feet.

These mountains vary also in colour. Some are dark brown streaked with gray, others light brown; both are wild and rugged, but the latter are more frequently indented by ravines than the former, and more distinctly stratified.

At the Cove of Muscat, the rock proved on examination to be serpentine, traversed by veins or strings of calcareous spar. Asbestus also is said to occur in it. It breaks into rhomboidal masses, and exhibits a tendency to stratification. Its strata, if such they are, appear to dip northwards at an angle of about 30″. The variety in the colours of this rock, particularly when exposed to the weather, may explain the streaked appearance of the mountains composed of it, and its unequal hardness, the ruggedness of their outline. This serpentine may be traced for a considerable distance towards the north-west, but on the south of Muscat is soon lost, and succeeded by a bed of soapy light-coloured slate or shale. Beyond this there is, on the south-west, a narrow valley, along which I proceeded fourteen miles inland. On one side I found, extending along the whole of that tract, a very lofty ridge or cliff of limestone. The colour of this limestone is very variable,—gray, red, yellow, brown, sometimes distinct, sometimes blended with other tints. The prevailing inclination of the strata is directed to the north-east at an angle which varies from 30° to 60°; but it is by no means uniform, and in many places may be seen convolutions like those which the layers of wood affect when turned by knots out of their regular course.

On the other side the hills are lower, and the strata more continuous and horizontal; they consist of limestone and clay intermixed as in what are called the Kunker banks in the valley of the Ganges, the Jumna, and other Indian rivers. The limestone forms hard nodules, which are collected and burnt. These strata oftendip in a contrary direction to those on the opposite bank. At the bottom of the valley are found agglutinated pieces of limestone and serpentin: the latter may be derived from a range composed of this rock which is found in the neighbourhood. Neither on the high ground nor in the valley is there in general the least appearance of soil, still less of vegetation. The surface is every where cracked as if it had been exposed to the action of heat.

Such is the country that fell under my observation; and the description I have given would, I think, apply to the whole district. There are several springs both warm and cold, and the places where they break out are generally indicated by a village and a few date trees. These springs are not met with as you advance into the interior of the country. The temperature of one which I visited I found to be $111\frac{1}{2}°$ Fahrenheit: the water was perfectly sweet, and used both for drinking and irrigation; it took its rise in a cave of red limestone. Sparry iron ore is found in the limestone: the relative position of the limestone and serpentin could not be determined.

BOMBARAK ROCK.

From Muscat I crossed the Persian Gulf, and having doubled Cape Jask made an insulated mountain known to mariners by the name of Bombarak rock, and called by the natives of the country Kohe Mubaruc or the Fortunate Hill. It consists of a limestone similar to that of Muscat: from the unequal hardness of the several beds of this rock, it exhibits a series of steps or terraces resembling those formed by the basaltic and amygdaloidal beds of the Jarn Ghat, the Boar Ghat, and the high mountains which separate the Concan and lower lands of India from the Decan: these limestone terraces are seen for a considerable way along the coast.

The Quoins or Coins rocks rise boldly from the sea, and in appearance and structure resemble that of Bombarak; they are situate nearly at the entrance of the Gulf of Persia.

KISHME ISLAND.

Of this island, which is from 80 to 90 miles in length, I saw only the north-eastern extremity. In this part are cliffs of limestone from 60 to 200 feet high, capped with coralline sandstone, which is sonorous, and yielding with difficulty to the stroke of the hammer. The sand thus agglutinated forms layers, ridges, and blocks. Beneath it are beds of white, gray, and yellow marl, divided into pillars or worn into caverns; and a few feet beneath, a calcareous bed resembling the kunkur or mortar of India, and containing in some parts numerous shells of oyster, clam, &c., and a prodigious quantity of coral.

No part of the island is lofty; the highest hills, which are in the interior, are said to be composed of the same strata as occur on the coast, and covered with brown sand like that of Muscat. The gravel and sand agglutinate readily on the application of moisture; a property which the builders turn to advantage. The sand near the shore is whiter, being made up of the detritus of shells and corals.

GOMBEROON.

This old settlement is situate on a plain. The stones which lay about were of limestone like that of Ormus, whence they had probably been imported. In the buildings are great quantities of corals and fossil shells. I did not visit the hills inland.

ORMUZ ISLAND

Presents an assemblage of peak sand ridges. This island is nearly 30 miles in circumference; but the only part which is level or habitable, is a promontory at the northern extremity, which is about 2 miles in length, about 3 miles across at its broadest part, and terminated by a sandy spit, upon which the Portuguese erected a fort. The rock most prevalent is of a dark brown or reddish colour, produced by iron; specular iron ore and ochre abound. Peaks of gypsum occur in some parts of the island, white as snow; the heat of the climate is intolerable: not a tree or plant of any description grows here, nor is there any spring or well of fresh water. Several springs and small lakes afford a strong brine, and deposit salt on their margins; but no rock of salt has been discovered. Below the hills are pieces of conglomerate, probably derived from the higher grounds, in which quartz and felspar are imbedded in a base of light-gray hornstone. There are also found in the state of pebbles greenish chert, plasma, dark-coloured slate clay, brownish or reddish flint, with particles of micaceous iron ore, a dark cellular stone with fragments ofshells, and chert or quartz coated with a saline efflorescence.

Copper pyrites crystallized in pentagonal dodecahedrons occurs abundantly in every part of the island.

Near the old town the hills rise very abruptly, and the connecting ridges are narrow and rugged. A nearly horizontal line may be traced along the crest of the high ground, denoting a change of substance. Above this line the rocks are of a dark brown colour, and rise into peaks or needles; all the ravines and slips are at a lower level. The detritus in the valleys readily agglutinates, notwithstanding the apparent paucity of calcareous matter.

LARREK ISLAND,

Which is equidistant from the islands of Ormur and Kishm, is said to consist of nearly the same substances, ferruginous rocks, iron ores, and gypsum with brine-springs. On the north and north-east it contains also limestone.

ARYAN ISLAND

Is situated close to Kishme island. Nearly in its centre ironstone and iron ore have been discovered in the bed of a torrent.

POLIOR ISLAND.

Specular iron ore has been found here also.

All the other islands, as far as information has been obtained, consist of the same rocks as occur at Kishme and Cape Bombarak. This appearance of the horizontal strata seen between Kishme and Bushire sanctions this opinion. The rocks at Muscat are likewise in all probability the same.

At Barn hill, situate on the coast of Congoom Bay, and rising to the height of perhaps 3000 feet, and at Cape Verdistan, the rocks are distinctly stratified. From thence to Bushire the hills are calcareous. Besides beautiful alabaster and other varieties of gypsum, they produce calcareous spar, which is used in making the finer sorts of cement.

The upper end of the Persian Gulf is very shallow. At Bushire there are not at a considerable distance from shore above 4 or 5 fathoms water; the peninsula is alluvial, consisting of sand or mud, often saline; the sands often rise into dunes. The bed nearest the surface is calcareous freestone or grit abounding in shells, which is called by the people of the country ghutch: beneath it are two other varieties of shelly limestone. Large masses of alabaster are found on the hills, brought down or exposed by winter torrents.

I propose to lay before the Society an account of the circumstances under which the turquoise occurs in the Feeroza mines at Nichapoor, and have sent a series of specimens illustrative of my present communication.

XXV.—*An Account of some Effects of the late Earthquakes in Chili. Extracted from a Letter to* HENRY WARBURTON, *Esq.* V.P.G.S.

By Mrs. MARIA GRAHAM.

DEAR SIR, London, March 4, 1824.

I SEND you, at your request, some extracts from my Journal concerning the great earthquakes which visited Chili during my residence in that country in 1822-3.

The first shock, by which the towns of Valparaiso, Melipilla, Quillota, and Casa Blanca were almost destroyed, and Santiago much damaged, was felt at $\frac{1}{4}$ past 10 o'clock in the evening of Tuesday the 19th of November 1822. It lasted 3 minutes. I was then residing about a mile from the coast at Quintero, situated on a promontory about 30 miles to the north of Valparaiso. It was a very still and clear moonlight night; the aurora australis had been visible, and some lightning had been seen over the Andes. In a few minutes after the first shock, there was another less severe; and from that time, the whole night long successive shocks were felt, twice in every five minutes, each lasting from $\frac{1}{2}$ to 1 minute. On the morning of the 20th, a little before 2, at 4, and at $\frac{1}{4}$ before 6 o'clock there were three violent shocks, and the earth continued trembling in the intervals. This day was hot and sunny, with wind; the night was clear and windy. On the morning of the 21st, at $\frac{1}{2}$ past 2, at 10 minutes before 3, at $\frac{1}{4}$ before 8, at $\frac{1}{4}$ past 9, and at $\frac{1}{2}$ past 10; and in the afternoon at $\frac{1}{4}$ past 1, and at 2, violent shocks were felt. The weather of this day was like that of the preceding. On the morning of the 22d, at $\frac{1}{2}$ past 4, at $\frac{1}{2}$ past 7, and at $\frac{1}{4}$ past 9, there were violent shocks. A little before 10 three successive loud explosions were heard, like the sound of heavy artillery, the earth trembling very much after each explosion. At 11 was another violent shock, and between that and 1 o'clock were 3 slight ones. The earth then remained quiet until $\frac{1}{2}$ past 7. This day there was a thick fog with cold drizzling rain. On the 23d, the shocks were less violent and frequent. This day was cloudy and mild. On the 24th, there were continual earthquakes until 11 at night. On the 25th, there was a severe shock at $\frac{1}{4}$ past 8 in the morning, and others until a little before 10. On the morning of the 26th, at $\frac{1}{4}$ before 3 there was a shock, which lasted nearly 2 minutes. This day we had a violent northerly wind, with rain, which was considered very unusual at this season. During my stay in Chili, from this time until the 18th of January 1823, continual earthquakes, more or less severe, were felt every day. Those on the 10th and 25th of December were the most violent after that of the 19th of November. I have learnt that after my departure the earthquakes continued; that they were very violent last July, and had not ceased altogether so late as last September.

The sensation experienced during the more violent shocks was that of the earth being suddenly heaved up in a direction from north to south, and then falling down again; a transverse motion also being now and then felt. There was on the 19th of November a general tremor felt, and a sound heard like that of vapour bursting out, similar to the tremor and sound which I remember to have observed at each jet of fire, while standing on the cone of Vesuvius during the eruption of 1818. The tremor between the shocks was shown to be real by the agitation of water in a glass; and during the shocks water or mercury placed in a glass was thrown over the edge in every direction. In the house where I resided, the furniture was all displaced with some degree of regularity, so as to range, not parallel to the walls which fronted to the north and south, but at a given angle diagonally. The sensation experienced on board of the ships that lay in the harbour of Valparaiso, was as if they were moving very rapidly through the water, and occasionally touching the ground. On the first shock on the night of the 19th of November, the sea in Valparaiso harbour rose to a great height, and then receded so as to leave the small vessels that were before afloat, dry on the beach: it then returned again, but, as compared with the level of the land, not to its original level. All this is stated to have happened in the course of a quarter of an hour.

On the morning of the 20th, all the rivers and lakes connected with them, in consequence of the dislodgement of snow from the mountains, were much swollen. In all the small valleys the earth of the gardens was rent, and quantities of water and sand were forced up through the cracks to the surface. In the alluvial valley of Viña a la Mar, the whole plain was covered with cones of earth about 4 feet high, occasioned by the water and sand which had been forced up through funnel-shaped hollows beneath them; the whole surface being thus reduced to the consistence of a quicksand. At the roots of all the trees, between the surrounding earth and the stem, large hollows were seen, into which the hand could be introduced, occasioned by the violence with which the trunks had been lashed to and fro. The bed of the lake of Quintero was full of large cracks, and the alluvial soil on its shore so divided as to look like a sponge: the level of the lake, which communicates with the sea, had apparently sunk very much. The promontory of Quintero consists of granite covered by sandy soil. The granite on the beach is intersected by parallel veins, from a line to an inch in thickness, most of which are filled with a white shining matter, but some are only coated with it on their sides, and present hollow fissures. After the earthquake of the 19th, the whole rock was found rent by sharp recent clefts, very distinguishable from the older ones, but running in the same direction. Many of the larger of these clefts might be traced from the beach to the distance of $1\frac{1}{2}$ mile across the neighbouring promontory, where in some instances the earth parted, and left the stony base of the hill exposed.

It appeared on the morning of the 20th that the whole line of coast from north to south, to the distance of above 100 miles, had been raised above its former level. I perceived from a small hill near Quintero, that an old wreck of a ship which before could not be approached, was now accessible from the land, although its place on the shore had not been shifted. The alteration of level at Valparaiso was about 3 feet, and some rocks were thus newly exposed, on which the fishermen collected the scallop shell-fish, which was not known to exist there before the earthquake. At Quintero the elevation was about 4 feet. When I went to examine the coast, accompanied by Lord Cochrane, although it was high water, I found the ancient bed of the sea laid bare and dry, with beds of oysters, muscles, and other shells adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia. I found good reason to believe that the coast had been raised by earthquakes at former periods in a similar manner; several ancient lines of beach, consisting of shingle mixed with shells, extending in a parallel direction to the shore, to the height of 50 feet above the sea. The country has in former years been visited by earthquakes, the last of any consequence having been 93 years ago.

The shock of the 19th was felt as far as Lima to the north by the ships then riding in Callao bay. To the south it was experienced at least as far as Conception; and to the East beyond the Andes, at Mendoza, and St. Tuan. The distance from Conception to Lima is about 20 degrees of latitude, or 1400 miles.

I am, dear Sir,

Yours, &c.

MARIA GRAHAM.

XXVI.—*Account of some Terraces, or ancient Beaches, in the Isle of Jura.*

BY CAPTAIN VETCH, ROY. ENG., M.G.S.

[Read February 21, 1823.]

TO those who speculate on the great general revolutions to which our planet was subjected in the early stages of its existence, it cannot but be interesting to contemplate any changes in the relative situations of land and water, which can be shown to have taken place on a more confined scale, and at a later period. Proofs of some such changes may, I think, be found on the western coast of the island of Jura; and if they have hitherto remained unnoticed, this is to be ascribed, not to the indistinctness of the phænomena which I am about to mention, but to the uninviting aspect of that island, which seen from the Paps, the highest point, and that to which every traveller would naturally repair in the first instance, appears to consist entirely of vast continuous beds of quartz; a detailed examination of which would ill repay the toil and privations, under which alone it could be undertaken, where the surface is so rugged, the accommodations so scanty, and the weather so precarious.

My own attention was first drawn to this subject on the summit of Ben an Oir, whence looking in the direction of Loch Tarbert, I observed a number of white patches, which I concluded, in the first instance, to be sheets of water. The telescope undeceived me; but being still ignorant of their true nature, I determined to visit them. On closer inspection, they proved to be blocks of quartz, lying upon six or seven terraces; the lowest of which was at the level of high-water mark, and the most elevated about forty feet above it. The aggregate breadth of these terraces varied according to the disposition of the ground; where the slope is precipitous it may be a hundred yards, where gentle, as on the north side of the Loch, three quarters of a mile from the shore.

Their extent, as far as I could trace it partly along the shores of Loch Tarbert and partly north and south of its entrance, may be eight or nine miles.

Their base is generally naked rock; but along the shore of Isla sound, and thence northward as far as Loch Tarbert, a thick bed of alluvium * composed

* Dr. M'Culloch's remark, that there appear no alluvia in Jura worthy of regard, must be received with this qualification.

of clay with some sand and angular pebbles of quartz. This bed when it reaches the sea is often undermined, and the line of terrace upon it consequently interrupted. Similar interruptions are sometimes occasioned by mountain torrents; and scanty as the vegetation is, it is still sufficient to render the continuity of the terraces in some places indistinct. On the surface of the terraces, situate (as I have said) sometimes on bare rock, sometimes on alluvium, we find a beach of round, smooth, white blocks of quartz as large as cocoa-nuts. These are common to all the terraces, and identical in their appearance with those which constitute on this side of the island the present beach of the Atlantic.

The width of the terraces, and the flatness of their surface, preclude the idea that they were formed by a sudden and violent inundation, or in any other way than by the action of tides and waves similar to those of the present sea. That such was their origin, is further confirmed by a series of caves which occur at one and the same level along a cliff on the north side of Loch Tarbert, some hundred yards inland, and at a considerable height above the level of the sea. Every other cave which I have seen in the quartz rock at Isla, Jura and Fair Island, is situate on the shore, and has or may have been produced by the action of the waves upon the cliffs:—those which are similarly distributed must be ascribed to a similar cause.

These phænomena do not appear to extend beyond the limits I have assigned to them. They are not seen on the east coast of Isla, nor in any of the adjacent islands. The alluvium at Bornou in Isla, upon which Dr. M'Culloch has reasoned, I think correctly, presents nothing analogous to the beaches I have been describing:—in regard to that of Kyle haven in the Isle of Skye, I am unable to speak with equal confidence.

If, then, the terraces now appearing at different heights above the sea have been each in its turn on a level with it, we can only account for their present position by assuming several successive subsidences of the sea, or as many successive risings of the land; but the effect of the former would have been felt all over the globe: the very limited area, therefore, over which these phænomena can be traced, necessarily inclined us to embrace the latter hypothesis.

XXVII.—*Notices and Extracts from the Minute-Book of the Geological Society.*

1. *Extract from two Letters dated Sierra Leone, June 3d,* 1822; *and Bathurst, St. Mary's, Gambia, July 20th,* 1822; *addressed by* Joseph Byerley, Esq. *to* B. Fayle, Esq., *and communicated to the Society by* Dr. Babington, *President.* [Read Feb. 21, 1823.]

THE hills round Sierra Leone are of granite, or rather of sienite-porphyry, composed of olive-green felspar in huge masses, with occasional mica and tourmaline. This rock decomposes, and forms a red loose aggregate which serves to build with, and is of the colour of red brick; the whole soil partaking of this colour, and giving a fine bistre tint to all the scenery, which forms a striking contrast to the great verdure of the woods. The scenery is highly picturesque and mountainous. Orange, lime, coffee, cotton, acacia, cocoa-nut, banana, palm, and other trees in wonderful variety, form a fine shade over the beautiful and romantic roads through the woods on the hills around. The pine-apples grow wild in the woods, and are very fine and abundant. Fine copal is brought by the natives from the interior, but it is not an article of trade, owing to the high duties in England. The governor has a coffee farm on the mountains, the scenery around which is very fine. In the fore-ground are rude fragments of dark olive-green felspar. Behind are higher mountains covered with woods that are always green; in the front down the valley is seen Sierra Leone, on its reddish brown soil, bounded by the mouth of the river and the ocean. The huts of liberated Negroes lie scattered here and there amidst the trees, adding greatly to the beauty of the scenery.

At Gambia there is only sand; but opposite to the town there are islands of red decomposed granite, part of which resembles iron slag. At Goree the rock is a fine basalt which takes a regular prismatic form, similar to the Giant's Causeway.

The castor-nut grows like a weed at Gambia; and large supplies of its oil might be obtained thence; but the duties in the mother country are quite prohibitory.

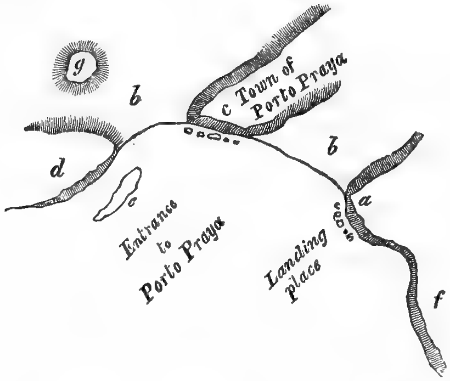
2.—*Notice respecting the Matrix of the Brasilian Diamond. By* H. Heuland, Esq. M.G.S. [Read May 16, 1823.]

THE diamonds imported into Europe from Brazil are almost always insulated. A few are imbedded accidentally, and some artificially, in a conglomerate called in America *cascalhao*, which is of alluvial origin, and consists of rounded pebbles held together by a ferruginous cement. The accompanying specimen, a small octaedral crystal, is the only one I have seen in its real matrix; it is surrounded by cupreous arseniate of iron (scorodite), and lies in a cavity of massive brown ironstone. It was found at Antonio Pereira, and is, I believe, the first diamond that has been found there. Mr. Caldcleugh, who is acquainted with the spot, informs me, that this ironstone occurs in veins or beds 25 feet thick, that it rests on chlorite slate, and may be traced to a great distance along the mountain chain. Baron Eschwege, superintendant of the mines, to whose kindness I am indebted for the specimen, in a memoir which he has lately published on the geology of Brazil, says that it is accompanied by micaceous iron ore and itabirite, by which is meant a compound partially slaty, partially granular, consisting of two varieties of specular iron ore, the common and micaceous, mixed occasionally with oxydulous iron ore and quartz. The mountain from which this compound derived its name is situate between Villa Rica and Sabará. It may be seen 10 leagues off, and at a distance has the appearance of a falling tower. The brilliancy of its metallic surface also catches the eye when some miles distant, and accounts for the appellation given it by the Indians, in whose language the words Ita bira signify the bright rock.

3.—*Notice accompanying Specimens from Porto Praya in St. Jago, one of the Cape de Verde Islands. Extracted from a Letter from* Major Colebrooke *to* H. T. Colebrooke, Esq. M.G.S. [Read January 2nd, 1824.]

THE town and fort of Porto Praya are seated on a tabular eminence (*c*) at the extremity of a bay formed by the headlands (*d* and *f*) with the rocky islet (*e*) detached from the former. Between the town and each of the two promontories, the valleys (*b b*) intervene, and form a sandy beach.

The cliff (*f*) exhibits a broad white surface half way up, conspicuous at a distance. This appearance would probably continue to the landing-place (*a*), but the structure of the rocks lies concealed under fragments and undercliff, and at (a), from the same cause, the inferior rock is alone visible; but at (c) the rocks again appear in the same relative situation as at (f), and afford every facility for examination.



The upper stratum is a dark coloured rock, apparently fused; and which might be called, from its external appearances, a compact lava. Abundant veins of arragonite intersect it and coat the surface of its cavities, and even cause it in some places to assume the appearance of a breccia. This breccia, which crowns the cliff, is of considerable depth, perhaps from 8 to 12 feet; its structure is tabular, and it separates into horizontal plates, some a foot in thickness. At the point of junction it is found of a red colour and decomposed, and the stratum below is also tinged for some short space with red. This lower stratum appears to be a tertiary limestone, containing the exuviæ of a large species of ostrea, and rolled pebbles of a rock similar to that by which it is surmounted. It lies in layers a foot or two in thickness, at (c) a little depressed to the south-east. Its substance is a greenish sand filled in parts with yellow pisolitic concretions, of which it is composed.

Inland appears a succession of tabular ridges with steep declivities. That on which the town is built, is about 500 or 600 yards broad. The hills are bare of vegetation, though perhaps covered with a scanty herbage in the rainy season. Cotton and coffee are grown: the soil is unpropitious for trees, and the palmyra, used in basket-making, is alone planted.

Inland, about 3 miles, is an outlying conical hill (g), rounded at the top, higher than the surrounding country, of a deep red colour, from which the material of a pottery, more compact than the English, is extracted; and some sparkling substance, probably pyrites, which it contains, the ignorant inhabitants imagine to be gold. Ranges of hills still higher, and of irregular outline, terminate the back ground, centring in a nearly perpendicular peak. There is no account of any modern volcano in the island.

4.—*Notice accompanying some Specimens from the Blue Chalk Marl of Bletchingley. By* Gideon Mantell, Esq. M.G.S. [Read Jan. 17, 1823.]

Observing in the excellent work on the geology of England, by Messrs. Conybeare and Phillips, that a question has arisen respecting the nature of the blue marl in the vicinity of Nutfield, Godstone, and Bletchingley in Surrey*; and the writer of the passage to which I refer (Mr. Wm. Phillips) also remarking that "although the marl strongly reminded him of the blue marl at Folkstone, yet he had not observed any organic remains," I take the liberty of transmitting to the Society a few fossils which I collected several years since from the foot of the hill near Bletchingley: they are as follows,

1. Inoceramus concentricus.
2. ——— sulcatus.
3. Nucula pectinata.
4. Rostellaria carinata.
5. Hamites intermedius.
6. Turbinolia Konigi.
7. Ammonites splendens.
8. Belemnites Listeri.
9. Dentalium.

From these specimens, it may be inferred that the deposit in question is identical with the Folkstone marl of Sussex, since nothing can be more decidedly characteristic of the latter than the organic remains above enumerated.

I would also beg to repeat, what I have elsewhere remarked (*vide* Illustrations of the Geology of Sussex, p. 83,) that the blue marl of Bletchingley contains layers of indurated reddish brown marl, similar to those which occur in the blue chalk marl of Norlington near Lewes.

5.—*Notice of the Discovery of a large Fossil Elephant's Tusk, near Charmouth, Dorset. By* H. T. De la Beche, Esq. F.R.S. &c. [Read May 2, 1823.]

Professor Buckland has already noticed the discovery of fossil elephants' tusks in the Charmouth diluvium†, which is composed of flint and chert mixed with clay, the result of the destruction of the chalk, green sand, and a portion of the lias marl, at the time of the formation of the valley. A small cliff of this diluvium, resting upon lias marl, on the western side of the mouth of the Char, is exposed to the action of high tides; it in consequence occasionally falls away, and its fossil contents may then be observed. The fossil tusks of elephants are the only remains of that animal which have as yet been found. In No-

* *Vide* Outlines of the Geology of England, p. 152.

† Geological Transactions, Second Series, Vol. I. p. 102.

vember last (1822) one of large dimensions was discovered. It was considerably curved, and measured $9\frac{1}{2}$ feet along its curvature; the workmen unfortunately destroyed the middle portion in attempting to extract it from the diluvium: the two ends are, through the kindness of W. Aveline, Esq. of Lyme, now in my possession. The fragment containing the thickest extremity measures 3 feet 3 inches in length, and 1 foot $6\frac{1}{2}$ inches in circumference at both ends. It preserved therefore the same thickness for that distance. It has a small cavity penetrating about 4 inches at its lower extremity. The other fragment contains the apex, and measures 1 foot $1\frac{3}{4}$ inch in circumference, at 1 foot 5 inches from the point.

About 2 years since, another elephant's tusk of much smaller dimensions was found near the same spot. Like the larger specimen, it is much curved; it measures 3 feet $6\frac{1}{2}$ inches along its curvature, and $11\frac{1}{2}$ inches in circumference at the thick end: this is also in my possession*. Three molar teeth of a fossil rhinoceros, and fragments of a large tusk of an elephant, have been found in a similar diluvium above the Church cliffs at Lyme.

6.—*On the Substances contained in the Interior of Chalk Flints. By* the Rev. J. J. Conybeare, M.G.S. [Read June 7th, 1822.]

In searching the chalk-pits of Broughton near Salisbury for organic remains, my attention was attracted by the frequent occurrence of flinty nodules, apparently moulded on alcyonia, the cavities of which, on breaking them, in lieu of the expected fossil, afforded only a white powder having the general aspect of a crumbly chalk, but feeling somewhat more gritty to the touch. In many cases these nodules had, as is usual with alcyonic flints, one or more traces of apertures. In others, no such trace was perceptible. The contents of one of these latter were carried home, and gave, on a rough analysis,

Carbonate of lime slightly tinged by iron	72
Silex in the state of a fine sand	28
	100

The siliceous sand *appeared* under a tolerable microscope to consist of angular rather than rounded particles; but its pureness was such as to render this point scarcely determinable without the aid of a higher magnifying power than

* Professor Buckland informs me, that about 15 years ago another small tusk, nearly of the same size, was found in the sand at the base of this same cliff, from which it clearly must have fallen, and was placed in the collection of H. H. Henley, Esq., of Sandringham, Norfolk.

I have at my command. From the great readiness with which even a very diluted acid took up the whole of the lime, its combination with the silex must have been purely mechanical.

The mass of the chalk in which the nodules were imbedded, affords scarcely a trace of siliceous admixture, though such an admixture may be found occasionally in the thick white crust with which some of the flints are invested; in this case, however, the silex forms by far the larger portion of the mass, and the lime appears somewhat more intimately combined with it.

7.—*Description of some Fossil Vegetables of the Tilgate Forest in Sussex.*

Mr. Mantell, M.G.S., of Lewes in Sussex, having favoured the Society with a collection of fossil vegetable bodies from the Tilgate forest, near Cuckfield, in that county, some members of the Council were appointed a committee to describe and publish them in the Transactions. In the prosecution of their labours, they have to acknowledge the invaluable assistance which has been liberally afforded them by our celebrated countryman Mr. Robert Brown.—The following information as to the locality of the fossils has been communicated to us by Mr. Mantell.

" The strata of Tilgate forest consist of various layers of sandstone and schistose calcareous sandstone lying on a bed of blue clay of considerable thickness. They emerge from beneath the upper beds of the iron sandstone; and the blue clay, on which they repose, is succeeded by beds of that formation. They traverse the county of Sussex in a direction nearly north-east and south-west: Horsham being their western, and Hastings their eastern boundary. The following section of a quarry in the vicinity of the forest will serve to convey a general idea of the whole.

" 1. (The lowermost bed.) A blue tenacious clay, destitute of fossils, depth unknown.

" 2. Compact blueish gray sandstone divided by horizontal seams of blue marl, into layers from 3 to 12 inches in thickness. This bed is about 9 feet thick. It contains the bones of two species of turtle, of a crocodile, a plesiosaurus, a megalosaurus, a cetaceous animal, probably a whale, of birds, and the vegetables about to be described. The upper layers are a compact conglomerate; but the lower are perfectly homogeneous, and contain shells, such as are found in the Sussex marble, and figured by Sowerby as a Vivipara.

" 3. Yellow sand and soft calcareous sandstone, alternating with thin layers of sandstone slate 7 feet thick, contains bones and teeth of crocodiles and of some unknown animals, fishes, turtles, birds, carbonized wood, vegetables, and casts of univalves and bivalves.

"4. A coarse aggregate of quartz, limestone, and sandstone pebbles, and immense quantities of comminuted bones and teeth of fishes, the whole loosely held together by a coarse grit. It varies in thickness from 3 to 6 feet.

"The vegetable fossils which form the immediate object of our investigation, are almost entirely confined to Nos. 2. and 3.; and in both of these beds are exceedingly abundant."

Partial subterranean floras, such as the present, will enable us to ascertain what different orders of vegetables have progressively clothed the successive crusts of our planet, and to identify strata by their fossil vegetation, equally as well as we now do by their zoological contents.

In the present instance we arrive at least at one interesting fact, in regard to that numerous fossil order the Ferns, which were before only known to range from their principal habitat the carboniferous series of rocks to the oolitic formation, in which they occur in the Stonesfield slate. We now find them in the ferruginous sandstone; but as yet they have not been detected in the chalk or in the beds above that great division.

The absence of the organs of fructification in fossil plants, the imperfect state of the plants themselves, and their anomalous character when compared with their recent congeners, have tended, as yet, to retard their study and arrangement. A system, however, founded on the few external characters they present, has been formed by Messrs. Schlotheim, Sternberg, and Adolphus Brongniart; but chiefly arranged and consolidated by the latter. This system, for the convenience of identification and comparison, it may be useful for us to adopt.

Plate XLV. figs. 1. 2. and 3. represent different portions of a trunk or caudex, scored on the surface, somewhat after the manner of those of the genera Zamia and Cycas, but altogether differing from them, or any other known family, in inclosing an internal body marked likewise on its surface; and that very differently so from the external covering. See Pl. XLV. fig. 1., Pl. XLVI. fig. 8., and Pl. XLVII. fig. 4. *a*. Between these is apparently interposed the cellular substance, represented moderately magnified Pl. XLVII. fig. 4. *d*. The markings on the inner surface sometimes appear decidedly imbricated; which has been carefully represented Pl. XLVII. fig. 4. *c*. A cicatrix, possibly that of a branch, has been drawn Pl. XLVII. fig. 4. *b*. This appearance, however, of the setting off of a branch from the inner surface, may be deceptive; and here the trunk of a Dracæna Draco, existing in

Mr. Brown's collection, presented us with something like an analogous construction. This tree possesses a thin outer bark, marked by the cicatrices of the leaves; and within that an internal, somewhat reticulated surface, in which we remarked a singular plexus of the vessels formed where the dragon's blood was secreted, to which the cicatrix in our vegetable bears a striking resemblance. It was right to allude to this fact, although we can rest but little upon it.

The marking on the external surface or bark, would induce us to arrange this most singular vegetable in the fossil genus Clathraria * of Mr. Ad. Brongniart. It differs, however, from this genus, in that each rhomb is surrounded more distinctly at the confluence of the obtuser angle, by an additional elevated ridge, Pl. XLVII. fig. 4. *a*. On this account, and from the singularity of its internal arrangement, we have named this species Clathraria anomala. The largest specimen of C. anomala yet found, Mr. Mantell informs us, measured 14 inches in circumference and 4 feet in length.

Pl. XLVI. figs. 1. and 2. represent a fossil vegetable, sometimes found considerably larger, but usually attenuated at the base, and swelling unequally at different intervals, after the manner of some of the Cacti. It is sometimes hatchet-shaped, very flat, and 12 inches wide, and at times is found encrusted by a carbonaceous matter difficult of preservation.

The dots on the section Pl. XLVI. fig. 2., and seen enlarged Pl. XLVII. fig. 5. *b*., indicate monocotyledonous structure. It is difficult to determine whether the larger cavities, dispersed irregularly through the substance, are the perforations of an animal, or the vestiges of internal organization. Probably they will be found to result from the latter. The eroded appearance of the surface is seen enlarged Pl. XLVII. fig. 5. *a*.

A mass of monocotyledonous wood from Upper Egypt, figured in the great work on that country published by the French Government, bears considerable resemblance to our plant. We have named it Endogenites erosa.

The fruit figured Pl. XLVI. figs. 3. and 4. is drawn enlarged Pl. XLVII. fig. 1. to show the veins on its surface. These veins may rather be considered as the impressions of the integument, than of the nucleus itself. We have named it Carpolithus (   ) Mantellii.

Pl. XLVI. fig. 5. and Pl. XLVII. fig. 3. represent a plant of the fossil genus Filicites. The ramifications of the veins, as given in the enlarged drawing, are of the highest importance; as through them alone, in conjunction with the form and habit of the frond, we can hope, in the absence of fructifi-

* This is a division of Sternberg's genus Lepidodendron: in neither is internal structure taken into account.

cation, to arrive at natural affinities; it being the chief failing of our system, and more particularly in this interesting family, that not only it is itself artificial, but that for the first time, and in the science of fossil botany alone, these subgenera are no longer natural, but altogether artificial divisions. Our present plant approaches in habit to some of the tropical Nephrodia; but the ramification of the veins, as seen at the tips of the pinnæ, distinguishes it from them. These veins will not exclude it, according to his definition, from Mr. Ad. Brongniart's subgenus Pecopteris; their interlacement, however, is curious, and we have named the species P. reticulata.

The plant figured Pl. XLVI. fig. 7. and XLVII. fig. 2. belongs likewise apparently to the genus Filicites, if indeed the ramification of the fronds, as indicated by the different planes in which the branches are disposed (so distinct from the mere distichous frond of the ferns), does not drive it out of this family. In this respect, as well as in the form of its frond, it approaches to Psilotum, the species of which differ remarkably from each other in the development and figure of those bifid branches, in the division of which the capsule is placed. But this idea is not supported by the disposition of the vessels in the ultimate segments, which more nearly resemble those of Trichomanes or Hymenophyllum. In the system of Mr. Ad. Brongniart, this plant would probably be a Sphenopteris, but differs both from his example of this subgenus figured, and from the recent analogous genera enumerated by him as having its form, in that all the divisions of the frond are bordered by a decurrent membrane as in the genus Trichomanes, with which, as we before said, it would likewise accord in the disposition of its vessels. We have therefore thought fit from the above natural characters to form a new subgenus under the name of Hymenopteris, although, if it could have been so arranged, we should have preferred distinguishing these fossil subgenera by a different termination, such as Hymenopterites, from the recent genera Struthiopteris and others. We are however unwilling, without absolute necessity, to alter what has been received, and we shall therefore call our plant Hymenopteris psilotoides.

In finishing this arrangement of the fossil flora of the Tilgate Forest, we are far from wishing to desert the subject; and should any member of the Society be possessed of similar remains, for the illustration of which he may be anxious, we should feel it our duty again to enter upon these interesting but obscure investigations.

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	Mineral Conchology, No. 50, by James Sowerby.	The Author.
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	Incendio del Vesuvio 19 d'Ottobre 1767, descritto dal P. D. Gio. M. della Torre, 4to, Napoli, 1767.	....
	Geographie de la France, 2 vols. 8vo, Paris, 1802.	....
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	Transactions of the Asiatic Society, vol. 13.	Asiatic Society.
	Mineral Conchology, No. 52, by James Sowerby.	The Author.
8.	Beschreibung der Gebirge von Baiern und der oberen Pfalz von Matthias Flurl, 8vo, Munchen, 1792.	G. B. Greenough, Esq. M.G.S.
Sept. 20.	Memoirs of the American Academy of Arts and Sciences, vol. 4th, part 2d, Cambridge, Massachusetts, 4to, 1821.	American Academy.
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	Journal of Science and the Arts, No. 23.	Royal Institution.
	Twelve Essays on the proximate Causes of the Material Phænomena of the Universe, by Sir Richard Phillips, 8vo, 1821.	The Author.
	Mineral Conchology, No. 54, by James Sowerby.	The Author.
	A Natural History of Crinoidea, or Lily-shaped Animals; with Observations on the Genera Asteria, Euryalé, Cornatula, and Marsupites, by J. S. Miller, A.L.S., 4to, Bristol, 1821.	The Author.
	Abhandlungen der Koniglichen Akadimie der Wissenchaften in Berlin, aus den Jahren 1812, 1813, 1814, 1815, 1816, 1817, 1818, 1819.	Berlin Academy.
Nov. 16.	The American Journal of Science and Arts, No. 2 of vol. 3.	Dr. Silliman.
17.	D'Aubuisson des Mines de Freiberg et de leur Exploitation, 3 vols. 8vo, Leipsic, 1802.	Dr. Daubeny, M.G.S.
27.	Annales des Mines, 1st, 2d, and 3d livraisons of vol. 6.	Conseil des Mines.
	Annals of Philosophy for July, Aug., Sep., Oct., Nov., Dec. 1821.	The Editor.
Dec. 22.	Transactions of the Horticultural Society, vols. 1, 2 and 3, and parts 1, 2 and 3 of vol. 4.	Horticultural Society.
	Description of the Island of St. Michael, comprising an Account of its Geological Structure; with Remarks on the other Azores, or Western Islands; by J. W. Webster, M.D., 8vo, Boston, 1821.	The Author.
	Journal of Science and the Arts, No. 24.	Royal Institution.
	Mineral Conchology, No. 56, by James Sowerby.	The Author.
	No. 2 of Zoological Researches in Java and the neighbouring Islands, by Thos. Horsfield, M.D. M.G.S.	The Author.
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Jan. 26.	Note sur une Combinaison de l'Acide Oxalique, avec le Fer trouvé à Kolonserux, près Berlin en Bohême, par M. Mariano de Rivero.	The Author.
	A Treatise on a Section of the Strata from Newcastle-upon-Tyne to the Mountain of Cross Fell in Cumberland; with Remarks on Mineral Veins in general; by Westgarth Forster, 2d edition, 8vo, 1821.	The Author.
	Mineral Conchology, No. 57, by James Sowerby.	The Author.
Feb. 21.	Descrizione mineralogica della Liguria da Giuseppe Mojon, 8vo, Geneva, 1805.	Dr. Marcet, M.G.S.
	Analyse des Eaux Sulphureuses et Thermales d'Aiqui, par J. Moyon.	....
26.	Breislak Sulla Giacitura di alcune Rocce porf. e granit. osservate nel Tirolo dal Sig. Mazzari Pencati.	Istituzione di Lombardia at Milan.
	Transactions of the Horticultural Society, vol. 4, part 4, 4to, London, 1822.	Horticultural Society.
	Description des Travaux d'Amalgamation des Fonderies de Halbruck près de Freyberg, par M. J. P. Fragoso de Siqueira, 4to, Dresden, 1800.	Dr. Daubeny, M.G.S.

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14.	Elements of Conchology, including the Fossil Genera and Animals, by T. Edward Bowdich, Esq.	The Author.
15.	A Treatise on the Deluge, by A. Catcott, Lond. 1761, 8vo.	W. H. Pepys, Esq. M.G.S.
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	Mineral Conchology, No. 59, by James Sowerby.	The Author.
	Journal of Science and Arts, No. 25.	Royal Institution.
April 19.	The Use of the Blowpipe in Chemical Analysis, and in the Examination of Minerals, by J. J. Berzelius, Member of the Academy of Sciences, Stockholm: translated from the French of M. Fresnel, by J. G. Children, Esq. M.G.S.	J.G. Children, Esq. M.G.S.
	A descriptive Account of the Island of Trinidad, by F. Mallet, Capt. of Engineers, 4to, London, 1802.	Sir Ralph Woodford, Bart.
	Annales des Mines, 4th livraison of vol. 6.	Conseil des Mines.
May 1.	Mineral Conchology, No. 60, by James Sowerby.	The Author.
	Sul Granito del Tirolo sovrapposto a Roccie Conchilifere del Conte Marzari Pencati Osservatore Veneziano, 20 Sep. 1820.	The Author.
	Marzari Pencati sul Tachigonimetro nuovo Stromento geodetico.	The Author.
	Sul Bacino del Rodano ecc. Memor. di Giuseppe Marzari Pencati.	The Author.
	Sull' Agro Trojano ecc. Memor. di Filippo Barker Webb, M.G.S.	The Author.
	Marzari Pencati Elenco delle Piante di Vicenza.	The Author.
	Philosophical Transactions abridged to the end of the year 1700, by John Lowthorp, 3 vols. 4to, 4th edit.	Rev. Dr. Cooke, M.G.S.
	Philosophical Transactions from 1700 to 1720, abridged by Henry Jones, 2d edition, 4to, 2 vols.	....
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	Journal de Physique for Feb., March, April, May, June, July, Aug., Sept., Oct., Nov., Dec., 1821.	R. Ferguson, Esq. M.G.S.
	Observations on the Geology of the United States of America, by W. Maclure, Esq. For. M.G.S.	The Author.
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29.	Journal of Science and the Arts, No. 26.	Royal Institution
July 1.	Mineral Conchology, No. 62, by James Sowerby.	The Author.
4.	Transactions of the Cambridge Philosophical Society, part 2d of vol. 1, 4to, Cambridge, 1822.	Camb. Philosophical Soc.
13.	Elements of Conchology, including the Fossil Genera, by T. E. Bowdich, Esq., part 2d, 8vo, Paris, 1822.	The Author.
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31.	Mineral Conchology, No. 55 and 63, by James Sowerby.	The Author.
Aug. 29.	American Journal of Science and Arts, No. 1 of vol. 5.	Dr. Silliman.
Sept. 4.	Mineral Conchology, No. 64, by James Sowerby.	The Author.
	Journal of Science and the Arts, No. 27.	Royal Institution.
	Mineral Conchology, No. 65, by James Sowerby.	The Author.
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	Sur les Caractères Zoologiques des Formations, avec l'Application de ces Caractères à la Determination de quelques Terrains de Craie, par Alex. Brongniart, For. M.G.S., 4to, Paris, 1822.	The Author.
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	Sur la Classification et la Distribution des Vegetaux Fossiles, par M. Adolphe Brongniart, 4to, Paris, 1822.	....
30.	Bidrag till narmare Kannedon af Finlands Mineralier och Geognosie, af Nils Nordenskiold, Berg-masture Corresp. Acad. St. Petersburg, &c., 8vo, Stockholm, 1820.	The Author.
	A Treatise on Minerals, Mines, and Mining, by W. Price, fol. London, 1778.	W. Pepys, Esq. M.G.S.

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30.	Mineral Conchology, No. 66, by James Sowerby.	Messrs. J. De C. and C. E. Sowerby.
	Ann. of Philos. for Jan., Feb., March, April, May, June, July, Aug., Sept., Oct., Nov., Dec., 1822.	The Editor.
Dec. 23.	Trans. of the Geological Society of Cornwall, vol. 2.	D. Gilbert, Esq. M.G.S.
30.	Essai Geognostique sur le Gisement des Roches dans les deux Hémisphères, par Alexandre de Humboldt.	Dr. Fitton, Sec. G.S.
	Journal of Science and the Arts, No. 28.	Royal Institution.
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Jan. 2.	Transactions of the Horticultural Society, Supplement to vol. 4, and part 1 of vol. 5.	Horticultural Society.
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	Transactions of the Asiatic Society, vol. 14.	Asiatic Society.
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Feb. 6.	Mémoire sur les Terrains de Sédiment supérieurs calcaréo-trappéens du Vicentin, par Alexandre Brongniart, 4to, Paris, 1823.	The Author.
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	Essai sur la Constitution Physique et Geognostique du Bassin à l'Ouverture duquel est située la Ville de Vienne en Autriche, par M. Constant Prevost.	The Author.
	Observations sur les Grès Coquillers de Beauchamp, par M. Constant Prevost.	The Author.
Mar. 3.	Bulletin général et universel des Annonces et des Nouvelles Scientifiques publié sous la Direction de M. le Baron de Ferussac, 8vo, Paris, 1822.	Dr. Fitton, Sec. G.S.
	De Ossibus fossilibus Animalis, I. C. Rosenmuller, 4to, Leipsic, 1794.	Thomas Smith, M.G.S.
5.	Trans. of the Royal Soc. of Edin. part 2 of vols. 7 and 8.	Royal Soc. of Edinburgh.
7.	Histoire Naturelle des Crustacés des Environs de Nice, par A. Risso, 8vo, Paris, 1813.	The Author.
	Mémoire sur deux nouvelles Espèces de Poissons du Genre Scopeles observées dans la Mer de Nice, par A. Risso, 4to, Paris, 1816.	The Author.
	Essai sur l'Histoire Naturelle des Orangers, Bigadiers, Limettiers, Cedrattiers, Limoniers, ou Citronniers cultivés dans le Departement des Alpes maritimes, par A. Risso, 4to, Paris, 1813.	The Author.
	Annales des Mines, 2 and 3 livraisons, 1822.	Conseil des Mines.
	Analytical Essay towards promoting the Chemical Knowledge of Mineral Substances, by M. H. Klaproth.	C. Stokes, Esq. M.G.S.
	Narrative of an Ascent to the Summit of Mont Blanc, Aug. 18, 1822, by F. Clissold, Esq. 8vo, Lond 1823.	The Author.
April 2.	Journal of Science and the Arts, No. 29.	Royal Institution.

1823.	BOOKS.	DONORS.
April 3.	Description of Fossil Teeth and Bones found in the Valleys of Thiede, near Lindenberge in Brunswick, by Carl Bieling.	Rev. W. Buckland, V.P. G.S.
	An Introductory Discourse, delivered to the Leeds Phil. and Lit. Soc. April 6th, 1821, by Charles Turner Trackrah.	Leeds Phil. and Lit. Soc.
19.	Trans. of the Linn. Soc., part 2nd, vol. 13.	Linnean Society.
May 16.	Geognostisches Gemalde von Brazilien und Wahrscheinliches Muttergestein der Diamenten, von Bar. von Eschwege, Weimar, 1822.	The Author.
	Essai Geognostique sur le Gisement des Roches dans les deux Hemisphères, par Alexandre de Humboldt.	The Author.
	Journal de Physique, for Jan., Feb., March, April, May, June, July, Aug., Sept., Oct., Nov., Dec., 1822.	R. Ferguson, Esq. M.G.S.
	Des Lignites, par Alexandre Brongniart.	The Author.
	A familiar Introduction to Crystallography, by Henry James Brooke, Esq. M.G.S.	The Author.
31.	Annales des Mines, livraison 1, vol. 7	Conseil des Mines.
	Reliquiæ Diluvianæ, or Observations on the Organic Remains contained in Caves, Fissures, and Diluvian Gravel, and in other Geological Phænomena, attesting the Action of an universal Deluge, 4to, London, 1823, by the Rev. W. Buckland, Prof. Min. and Geol. Oxford, and V.P. G.S.	The Author.
	De Indole et Origine Aërolithorum, Iohannes Outzen Bjorn, 8vo, Othiniæ, 1816.	W. C. Trevelyan, Esq. M.G.S.
	Traité du Flux et Reflux de la Mer, par R. Jacques Alexandre, 12mo, Paris, 1726.	....
	Conchological Tables, compiled chiefly for the use of Shell Collectors, 12mo, Newcastle-upon-Tyne, 1823.	....
June 6.	Transactions of the Royal Society of Edinb. part 2, vol. 9.	Royal Society of Edinb.
	The Hunterian Oration, delivered in the Theatre of the Royal Coll. of Surg. in London, on the 14th of Feb. 1823, by Sir W. Blizard, Knt., Pres. of the Coll. &c. 4to, London, 1823.	The Author.
	On some Fossil Bones discovered in Caverns in the Limestone Quarries of Oreston, by Joseph Whidbey, Esq. F.R.S. to which is added a Description of the Bones by W. Clift, Esq. from the Phil. Trans. 4to, 1823.	W. Clift, Esq. M.G.S.
16.	An Index to the Historia Conchyliorum of Lister, with the Name of the Species to which each Figure belongs, and occasional Remarks, by L. W. Dillwyn, F.R.S. &c.	The Author.
	Trans. of the Linn. Soc. part 1, vol. 14.	Linnean Society.
	On the Stratification of Alluvial Deposits, and the Crystallization of Calcareous Deposits, in a Letter to John M'Culloch, M.D., by H. R. Oswald.	The Author.
	Part 2 and 3 vol. 5. Trans. of the Hortic. Soc.	Horticultural Society.
	Parts 1 and 2 of vol 6. American Journal of Science.	The Editor.
	Transactions of the American Philosophical Society of Philadelphia, vols. 1 to 6 inclusive, 4to.	American Philosophical Society of Philadelphia.
	Catalogue du Cabinet de M. Davila, 2 vols. 8vo, Paris, 1767.	W. C. Trevelyan, Esq. M.G.S.
	Klein Descriptiones Tubulorum marinorum, et Sciagraphia lithologica curiosa, 4to.	....
	Hints and Observations respecting the Collieries, by W. Thomas, Esq.	....
	Theorie des Vents, par M. le Chevalier de la Coudraye, 8vo, Fontenay, 1786.	....
	Gebri Regis Arabum Chemia, 12mo, Gedani 1682.	....

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Mémoire Geologique sur les Terrains du Bas Boulonnais, par F. Garnier.	Society of Agriculture, Boulogne.
Essai d'un Exposé Geognostico-botanique de la Flore du Monde primitif, par Gaspard Comte de Sternberg.	The Author.
Essai sur la Constitution Geognostique des Pyrénées, par I. de Charpentier, Directeur des Mines du Canton de Vaud.	The Author.
Descrizione Geologica della Provincia di Milano, da Scipione Breislak, 8vo, Milano, 1822.	The Author.
Report on the Roads and Mines of the Estate of Greenwich Hospital, by Edward Hawke Locker, Esq.	The Author.
Ann. of Philos. for Jan., Feb., March, April, May, June, July, Aug., Sept., Oct., Nov., Dec., 1823.	The Editor.
Lettre de M. Leopold de Buch à M. de Humboldt, renfermant le Tableau geologique du Tyrol meridional.	The Author.
Phil. Mag. for Jan., Feb., March, April, May, June, July, Aug., Sept., Oct., Nov., Dec., 1823.	The Editors.
New Theory of the Formation of Veins, with its Application tot he Art of working Mines, by Abraham Gottlob Werner.	Purchased out of the Fund for procuring Cabinets, Books, and Maps.
Mémoires du Museum d'Histoire Naturelle, par les Professeurs de cet Etablissement, vols. 4 to 10.	....
Recherches sur les Ossemens Fossiles, par M. le Baron G. Cuvier, For. M.G.S., nouvelle edit., tom. 1, 2, 3, 4, et premiere partie du tome 5.	....
A Nat. Hist. of Crinoidea, or Lily-shaped Animals, with Observations on the Genera Asteria, Euryale, Comatula, and Marpusites, by J. S. Miller, A.L.S., 4to, Bristol, 1821.	....
Dictionnaire des Sciences Naturelles, par plusieurs Professeurs du Jardin du Roi et des principales Ecoles de Paris, vols. 1 to 28, and 26 nos. of plates, and 3 livraisons of portraits.	....
Précis de la Geographie Universelle, ou Description de toutes les Parties du Monde, par M. Malte Brun, 2nd edit. 8vo, Paris, 1812, 5 vols. and an Atlas.	....
Dictionnaire des Postes aux Lettres du Royaume de France, par A. F. Lecousturier, 4 vols. 8vo, Paris, 1817.	....
Description of Hindostan and the adjacent Countries, by Walter Hamilton, Esq., 2 vols. 4to.	....
Recueil des Planches des Coquilles Fossiles des Environs de Paris, par M. Lamarck, 1 vol. 4to.	....
Keferstein's Geological Journal, nos. 1 to 5, 8vo, Weimar.	....
Frieselben's Geognostical Works, 6 vols. 8vo, Freyberg.	....
Engelhart's Method of Geognostic Inquiries, 12mo, Riga, 1817.	....
Rhode's Contribution to the Flora of a former World, 2 parts, folio.	....
Sternberg's Flora of a former World, 2 parts, folio.	....
Steinger's Geognostic Studies, 8vo, Maing, 1819.	....
——— New Supplement, do. do.	....
——— Chart on Rocks, do. do.	....
Englehardt, Rocks of Russia, folio, Berlin, 1820.	....
Raumer, Rocks of Lower Silesia, 8vo, Berlin, 1819.	....
Schlotheim on Petrifactions, 2 vols. 8vo, Gotha, 1820.	....

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1822.		
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	North View of the Riesengebirge from Frost, near Schmiedeberg to the little Shed built for shelter.	....
	Map of the Road from Milan to the three Lakes Maggiore, Lugano, and Como.	....
	Map of the Papal States, as divided by the French into Departments.	....
	Map of Styria, Carinthia, and Carniola, by De Castro.	....
April 15.	East and West Section of Ireland, from Newcastle in the County of Down, to the Sea below Benbulben in the County of Sligo.	Rich. Griffith, Esq. Hon. M.G.S.
19.	Map of the Island of Trinidad.	Sir R. Woodford, Bart.
Aug. 7.	One Sheet of the Ordnance Map of Middlesex.	Major Colby, M.G.S.
Oct. 4.	Map of Lanzarote, by Leopold von Buch, For. M.G.S.	The Author.
Dec. 23.	Lithographic View of a Mountain of Dolomite in Tyrol, in the Valley of Groden.	Leopold von Buch, For. M.G.S.
1823.		
Feb. 16.	Lithographic Map of the Isle of Paxo.	Dr. Fitton, Sec. G.S.
June 26.	Section of the Coal Strata at Cyfartha, Glamorganshire.	Dr. Wollaston, M.G.S.
	Map of the Environs of Dresden.	Dr. Fitton, Sec. G.S.
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	—— von Swabia, par Koleberger.	....
	La Suisse, par Weiss.	....
	La Silesie Supérieure et Inférieure.	....
	Carte du Rhin, partie de la Carte de Cassini.	....
	—— d'Assemblage de la grande Carte par Cassini.	....
	Map of Austria.	....
	Geological Map of France, par M. D. Halloy.	....
	Gotthold's Map of Germany, coloured geologically, being a Copy of M. Von Buch's reduced Map of that Country not yet published, taken by permission of the Author.	....
	Map of Poland, by A. P. H. Nordmann, 9 sheets.	....
	——— Saxony, by Jos. Dirwaldt, 1816.	....
	Post-map of Bavaria.	....
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	Specimens from Normandy.	H. T. De la Beche, Esq. M.G.S.
July 13.	Siliceous Casts in Perforations in Belemnites.	Thos. Allan, Esq.
16.	Two Specimens of Gypsum with Impressions of Leaves from la Stredella near Pavia.	Sig. Breislak.
Aug. 1.	Specimens from Trinidad, Montserrat, Antigua, and the Caraccas.	Sir Ralph Woodford, Bart.

1821.	SPECIMENS.	DONORS.
Aug. 8.	Fossil Fish in a Nodule of Limestone.	
	Specimens from New South Wales, collected by Mr. C. Frazer, the Colonial Botanist, by order of Governor Macquarrie, for the Geological Society.	By the hands of T. H. Scott, Esq.
	Specimens from Van Dieman's Land.	. . . .
Oct. 11.	Impressions of Encrini in Schist, from Plymouth.	Rev. Rich. Hennah.
Nov. 16.	Specimens from the District of Tortworth, Gloucestershire.	T. Weaver, Esq. M.G.S.
	Specimens from the East Indies.	Benj. Babington, Esq.
	Plaster Cast of the Head of a Fossil Rhinoceros found in Siberia.	Prof. Buckland, V. P. G.S.
27.	Fossils from Blackdown and Trilobites from Normandy.	C. Stokes, Esq. M.G.S.
	Specimens of Granite from Aberdeenshire.	Dr. Henderson.
Dec. 8.	Specimens from Cornwall.	Dr. Daubeny, M.G.S.
14.	Aggregated Cubes of Fluor Spar forming Octohedra; from the Beer Alston Lead and Silver Mines, near Tavistock, Devon.	D. Ross, Esq.
	Specimens from Jersey.	W. Lowe, Esq.
21.	Specimen of Amianthus, of fibrous chatoyant Quartz, and of yellow Sand from the Griqua Country, 700 miles from the Cape of Good Hope.	The Curators of the Col. of Surgeons, by the hands of W. Clift, Esq. M.G.S.
	Specimens collected on a Journey from Delhi to Bombay.	J. B. Fraser, Esq.
1822.		
Jan. 4.	Fossil Oysters from Castagna, Volterrano.	G. B. Greenough, Esq. M.G.S.
	Two groups of Rock Crystals from Oisans in Dauphiné.	H. Heuland, Esq. For. Sec. G.S
25.	Specimens of Lava from Vesuvius, of the Eruptions of 1819 and 1820, with Impressions of Medals.	The Duca de la Torre and Sig. Gimbernat.
26.	Specimens from Bermuda.	Capt. Vetch, M.G.S.
	Fossils from Blackdown.	C. Stokes, Esq. M.G.S.
	Septarium from Booforth, near Kirby Moorside, Yorkshire.	John Gibson, Esq.
	Fossils from Heddington Clay and Kelloway.	H. Warburton, Esq. M.G.S.
	Specimen of Chert from Halkin-hill, Flintshire.	A. Aikin, Esq. M.G.S.
Feb. 23.	Specimen of Coal, showing a fibrous Structure, from the neighbourhood of Dunfermling.	Thos. Allan, Esq.
26.	Stalactites from the Sandwich Islands.	Henry Heuland, Esq. For. Sec. G.S.
	Calk Tuff of Werner, with Impressions of Plants from Aigue Blanche, Mont Blanc.	
	Fossil Wood bored by the Teredo from the neighbourhood of Harwich.	Capt. Marryatt.
	Specimens from Attica.	J. Woods, Esq. M.G.S.
27.	Specimens from Cornwall.	Dr. Daubeny, M.G.S.
	Specimens from the Rock of Gibraltar.	C. H. Turner, Esq. M.G.S.
Mar. 14.	Specimens from the neighbourhood of Cuckfield.	Capt. Vetch, M.G.S.
	Specimens of fossil Shells from Tunbridge Wells.	Sir A. Crichton, M.G.S.
	Fossil Wood from the Weald of Sussex.	G. Mantell, Esq. M.G.S.
	Fossil Bone from the Ferruginous Sand.	Capt. Vetch, M.G.S.
20.	Specimens from Haldon.	Rev. John Rogers.
	Specimens of simple Minerals and Rocks from S. Carolina.	Chevalier de Onis, M.G.S
	Specimens from Shetland.	Capt. Vetch, M.G.S.
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29.	Part of a Fossil Vegetable, Coal Mines in Shropshire.	John Rose, Esq.
April 15.	Fossil Palate from a Chalk Pit near Leatherhead.	Miss Clarke.
	Specimen of a Rock composed of Fragments of recent Coral from Loo Choo.	C. Stokes, Esq. M.G.S.
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	Specimens of English Strata.	C. Lyell, Esq., M.G.S.
May 1.	Specimen of Mellilite from Capo de Bove.	A. Majendie, Esq., M.G.S.
11.	Glauberite in its Gangue, Salt Mine of Vela Rubia, Spain.	W. Maclure, Esq.
	Specimens from Wolmer Forest.	M. Wright, Esq.
	Fossil Ammonite from the Neighbourhood of Rouen.	A. Majendie, Esq., M.G.S.
	Fossils from Hordwell Cliff and Alum Bay.	Miss Benett.
	Specimens from the Quarries of Stonesfield.	H. Hakewill, Esq., M.G.S.
	Specimens from Spain.	Chas. Silvertop, Esq.
	Specimens of Magnesian Limestone.	Rev. A. Sedgwick.
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	Specimen of Ecume de Mer from Spain.	Chas. Silvertop, Esq.
	Specimens from Northumberland.	Matthew Culley, Esq.
	Fossil Ammonites from India, called by the Hindoos Salagram.	Dr. Wallich, M.G.S.
6.	Two Fossil Tusks and other Bones of the Mammoth found at Ilford in Essex.	J. W. Russell, Esq. M.G.S.
	Specimens of various Rocks fused by a Furnace.	Rev. J. J. Conybeare, M.G.S.
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	Specimens from the Quartz Rock of Bromsgrove Lickie.	Rev. Jas. Yates, M.G.S.
	Specimens from the East Indies.	Major Colebrooke.
	Specimen of Native Magnesia from Unst in Shetland.	Dr. Wollaston, V.P. G.S.
	Fossils from Grignon, and Specimens from a Gravel-pit near Castle Hedingham, Essex.	Ashhurst Majendie, Esq. M.G.S.
13.	Wood undergoing the Process of Petrifaction, from an old Wall.	Rev. J. J. Conybeare, M.G.S.
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	Specimens from the Weald of Sussex.	G. Mantell, Esq., M.G.S
	Specimens from South America.	Dr. Wollaston, V.P.G.S.
21.	Specimens from the Bahama Islands, in illustration of a Paper by the late Rev. John Wright.	Rev. W. Buckland, V.P.G.S.
July 6.	Specimens from New Zealand.	Sir Humphry Davy, Bart., M.G.S.
8.	Specimens from the Neighbourhood of Milden Hall, Suffolk.	Sir H. Bunbury, Bart.
31.	Portion of a Septarium from the London Clay.	Dr. Babington, Pres. G.S.
Aug. 7.	Specimen from Lyme, with Stems of Pentacrinites.	Rev. W. Buckland, V.P.G.S.
13.	Recent Skull of a Greenland Bear.	John Harwood, Esq.
15.	Fossil Bones found in Kirkdale Cave, Yorkshire.	John Gibson, Esq.
	Fossils from the Environs of Brussels.	C. Lemon, Esq. M.G.S.
	Specimens from Pulo Nias and Sumatra.	Dr. Jack, M.G.S.
Sept. 9.	Fossils from Maestricht.	Henry Smithers, Esq.
	Specimens of recent petrified Wood.	Rev. J. J. Conybeare, M.G.S.
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Oct. 28.	Five skeleton Models of Crystals.	N. J. Larkin, Esq. M.G.S.
	Specimens from South Africa.	H. T. Colebrooke, Esq. M.G.S.
30.	Specimens of Fossil Fish from Solenhofen in Franconia.	H. Heuland, Esq. For. Sec. G.S.

1822.	SPECIMENS.	DONORS.
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Dec. 6.	Cast of the under Jaw of the Plesiosaurus in the possession of H. T. De la Beche, Esq.	F. Chantrey, Esq. M.G.S.
	Specimens of Flints with organic Remains from Headingham Castle, Essex.	A. Majendie, Esq. M.G.S.
	Simple Minerals from Finland.	Nils Nordenskiold, Esq. For. M.G.S.
	Fossil Bones found in the Limestone Quarries at Oreston near Plymouth.	W. Clift, Esq. M.G.S.
20.	Shells in Grauwacke Slate from the Glyder Bach near Capel Carig.	C. Stokes, Esq. M.G.S.
1823.		
Jan. 2.	Specimens of Belemnites.	Richard Taylor, Esq.
3.	Specimens of Endellion and Carbonate of Iron.	C. Stokes, Esq. M.G.S.
17.	Specimens from the Lower Rake's Mine, Matlock, Derbyshire.	Dr. Daubeny, M.G.S.
	Fossils from the Blue Marle of Bletchingley.	G. Mantell, Esq.
Feb. 6.	Head of the Plesiosaurus, figured in Pl. XIX. Part 1. Vol. 1. 2d series of the Trans. Geol. Soc.	T. Clarke jun., Esq.
	Specimens of Fossils from the Stonesfield Slate.	C. Lyell, Esq. Sec. G.S.
	Specimens of Yellow Copper Ore.	J. Taylor, Esq. Treas. G.S.
	Specimens from St. Helena.	Col. Wilks, M.G.S.
	Specimens from Mont Blanc.	F. Clissold, Esq.
17.	Specimens illustrative of a Section of Stammerham and Sedgewick Quarry, near Horsham.	C. Lyell, Esq. Sec. G.S.
	Fossils from the Chalk near Dorking.	....
March 5.	Specimens of Arragonite from Bastern in Dax.	Rev. T. E. Rogers, M.G.S.
20.	Specimens of Rocks from Rio Janeiro.	A. Caldcleugh, Esq. M.G.S.
	Specimens of Flints with organic Remains, from a Gravel Pit near Headingham Castle, Essex.	A. Majendie, Esq. M.G.S.
April 18.	Specimens of Rocks in contact with Trap from the Great Whin Dyke in Yorkshire.	Rev. A. Sedgewick, M.G.S.
	Specimens from the Isle of Portland.	....
	Specimens of Oolite from Yorkshire.	....
19.	Fossil Turrilite from Beachy Head.	Dr. Wollaston, V.P.G.S.
	Specimens of the Bradford Encrinite.	C. Stokes, Esq. M.G.S.
May 1.	Specimens of recent Crabs and Shells.	Miss Benett.
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	Specimen of Granite from Lundy Island.	....
	Do. do. from Dartmoor.	....
	Specimens of Old Red Sandstone with Shells, Bristol.	....
	Specimen of Wavellite.	....
	Substance found near Biddeford, and used as a black Pigment.	....
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	Specimens from Limoges.	M. Schmitz.
28.	Echinus in Flint, Southfleet.	Miss Benett.
31.	Specimens of Rocks brought home from the Arctic Seas by Captain Parry.	Sir G. Clerk, Bart. M.G.S.
	Models of Fossil Bones found in the Environs of Paris.	M. le Baron Cuvier, For. M.G.S.
	Specimens of Rocks from the Puy en Velai.	Ecole des Mines.
	Specimens from the North-East of France, and South of Belgium.	B. de Basterot, Esq.
June 16.	Specimens from the Chain of the Vosges.	Ecole des Mines.

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	Specimens from Paris Basin.	M. Schmitz.
	Specimens from Forfarshire, N. Britain.	C. Lyell, Esq. Sec. G.S.
	Specimen of the Fin of a Balista.	Rev. Lansdown Guilding, M.G.S.
	Specimens collected in a Journey from Bushire to Teheran, Persia.	J. B. Fraser, Esq. M.G.S.
	Specimens from New York.	G. B. Greenough, Esq. V.P.G.S.
	Specimens from Madeira.	T. Bowdich, Esq.
	Specimens of Stalactite from Kirkdale Cave.	W. Salmond, Esq. M.G.S.
	Specimens from Madeira.	Major Colebrooke.
	Specimens from the Ferroe Islands.	W. C. Trevelyan, Esq. M.G.S.
	Specimens to illustrate a Plan of Part of the Coast of Northumberland.	....
	Specimens of Lias from Lyme Regis.	H. T. De la Beche, Esq. M.G.S.
	Specimen of recent Coral from Antigua.	S. Turner, Esq. M.G.S.
	Carbonate of Zinc disseminated through Clay from the Red Marl, Salturn Bay.	Rev. S. Holme.
	Charnites from the Green Sand.	Hon. Will. T. H. Fox Strangways, M.G.S.
	Plaster Cast of the Jaw of the Mastodon found in Austria.	Count Breunner, M.G.S.
	Specimens of Ores of Silver.	J. Taylor, Esq. Treas. G.S.
	Fossils from Scarborough.	H. T. Colebrooke, Esq. M.G.S.
	Specimens of Rocks collected on a Journey from Hyderabad to Madras.	H. W. Vasey, Esq.
	Three Fossil Fish from the Purbeck Beds, Isle of Purbeck.	H. Warburton, Esq. M.G.S.
	Specimens of Calciferous Sandstone from Hollington, with Impressions of Univalves and Bivalves.	Rev. J. Yates, M.G.S.
	Specimens of Soil from the Intertropical Coasts of New Holland.	Capt. King, R.N.
	Specimen of the Bed immediately below the Chalk at Compton, near Guildford, usually called in that country Black-land.	G. B. Greenough, Esq. V.P. G.S.
	Specimens from Siam and Cochin China.	J. Crawford, Esq. M.G.S.
	Specimens from Van Dieman's Land.	C. Stokes, Esq. M.G.S.
	Equiaxe Carbonate of Lime, and Magnesian Carbonate of Lime.	A. Caldcleugh, Esq. M.G.S.
	Phosphate of Lead from Huel Alfred Mine, Cornwall, and a new Variety of Blende from the Mine called Fowey Consols, near Fowey, Cornwall.	J. Taylor, Esq. Treas. G.S.
	Specimens from St. Jago, one of the Cape de Verd Islands.	Major Colebrooke.
	Specimens of Carbonate of Lead from Lord Ribblesdale's Mines, near Malham Tarn, Yorkshire.	H. Warburton, Esq. M.G.S.
	Specimen of Trap from the East Coast of Greenland, lat. 74.° 30′.	Capt. Sabine.
	Series of Specimens of Magnesian Limestone from the South of the River Tees.	Prof. Sedgwick, M.G.S.
	Recent Shells, Corals, Sponges, and Volcanic Rocks from St. Vincent, Specimens of Roc s from Antigua, and miscellaneous simple Minerals.	Rev. L. Guilding, M.G.S.

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END OF THE FIRST VOLUME,

SECOND SERIES.

PRINTED BY RICHARD TAYLOR,
SHOE-LANE.

PLATES AND MAPS

IN ILLUSTRATION

OF

VOLUME I.

SECOND SERIES,

OF

THE TRANSACTIONS

OF

THE GEOLOGICAL SOCIETY.

LONDON:

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SOLD AT THE HOUSE OF THE GEOLOGICAL SOCIETY,

No. 20, BEDFORD STREET, COVENT GARDEN.

1824.

EXPLANATION OF THE PLATES.

PLATE XXV.

Fossil Orthoceræ from Thessalon Island, Lake Huron: page 198.

The three figures in this plate (drawn of the natural size) belong to the same species, and exhibit a remarkable structure in the siphuncle, which is large in proportion to the size of the shell, and is dilated between each of the septa. It contains within it a tube running throughout its whole length, diminishing towards the lower end of the shell, and having radii in verticillations connected with the sides between each enlarged portion of the siphuncle.

Fig. 1. shows the external form of the lower part of the shell; and in the upper portion, the siphuncle laid open, and the verticillated radii distinctly separate from each other.

Fig. 2. represents the siphuncle laid open, but the radii have not been preserved in this specimen. The interior tube diminishes irregularly towards the smaller end, and seems to indicate that this part was formed of a substance which could be dilated or contracted. This figure is drawn in an inverted position.

Fig. 3. represents the form and size of the shell and siphuncle, with its internal tube. The radii are wanting in this specimen.

PLATE XXVI.

Orthoceræ from Lake Huron: page 196.

The figures in this plate exhibit varieties in the external form of the shells, and of the form and proportionate size of the siphuncle. There is also great difference in the size of the chambers as shown by the different distances between the septa. These differences are sometimes considerable in the same specimen, as in figs. 3 & 8.

PLATE XXVII.

Four views of the natural size, of a new species of Trilobite, named by Mr. Stokes, Asaphus platycephalus, from St. Joseph's Island, Lake Huron: p. 199. 208.

Fig. 1. *a*. Upper view of the anterior part, showing the position of the eyes, and the lines of the sutures; which, as in all the species of this tribe, divide the shelly crust at the eyes, and pass in a curved line near to the anterior margin; at the centre of this margin another suture joins the curved one, and passes round to the under side.

Fig. 1. *b*. Under view of the same. From the centre of the anterior margin, the straight suture above mentioned passes along the middle of this under side, till it meets another suture, where a plate, of the peculiar form represented in the figure, is attached. This plate of peculiar form has been detached at its suture by compression. Its upper margin is rounded at each side, and its lower part has a deep tumulated indentation, which was evidently the entrance into the stomach. This is the part mentioned in page 208.

Fig. 1. *c.* Side view of the same, showing the remarkably flat form of the specimen, from which peculiarity the specific name has been taken. The shelly crust of the under side joins the upper at the sides. This is usually the case with trilobites in this anterior portion of the animal.

Fig. 2. Posterior part of the same species.

PLATE XXVIII.

Fossil corals of the genus Huronia, from Drummond Island, Lake Huron. These corals are described in page 202.

Fig. 1. Huronia Bigsbei.
2. ——— vertebralis.
3. ——— turbinata.
4. ——— obliqua.
5. ——— spheroidalis.
6. Section of H. vertebralis.

The generic character of these corals is thus described by Mr. Stokes, who has given them the above names :

Polyparium stony, forming a straight jointed column of single cells placed one over the other; each joint having been in succession the habitation of the living individual. The remarkable peculiarity which establishes these corals as a particular genus is, that as a new generation arises, it forms its cell precisely over the preceding one, covering its upper surface entirely, and lengthening the column of the coral by a new joint in a continuous line with those previously formed.

PLATE XXIX.

Fossil corals from Drummond Island, Lake Huron.

Figs. 1, 2. *a.* 2. *b.* represent a species of Caryophyllia, remarkable for the tubes proceeding from it, as described in page 203.

Fig. 3. Very small species of Turbinolia.

Fig. 4. A species remarkable for the arrangement of the plates in the centre.

Fig. 5. Another species of Turbinolia.

Fig. 6. A species of Caryophyllia.

EXPLANATION OF THE PLATES.

PLATE XXX.

Figs. 1 & 2. Two species of Orthocera, mentioned in page 204.

The other figures in this plate represent the columns of circular discs mentioned in page 204; but it has not yet been ascertained to what class of fossils they belong.

PLATE XXXI.

Map of Lake Huron.

For the authorities from which it is compiled, see p. 177 of this volume.

PLATE XXXII.

Fig. 1. represents a section passing from north-north-west to south-south-east, through Blaze Castle, the Bristol coal basin, and Downhead upon Mendip. In figures 1 A. 1 B. and 1 C., the line of section is partially changed.

Fig. 2. represents a section passing from north to south through Tortworth, the Bristol coal basin, and Lyal hill near Wells. In figures 2 A. and 2 B. the line of section is partially changed.

Fig. 3. represents a section passing nearly from north to south through Portishead, the Nailsea coal field, and Cheddar. In figures 3 A. 3 B. 3 C., the line of section is partially changed.

Fig. 4. represents a section passing from west to east through Henbury, the Bristol coal basin, and Wyck rocks near Bath.

Fig. 5. represents a section passing from north-west to south-east through Little Doward Hill, the coal basin of the Forest of Dean, and Blakeney Hill.

PLATE XXXIII.

Fig. 1. is a plan of the Clifton defile, from Rownham ferry to Hungroad.

Fig. 2. is a section of the strata on the north-eastern bank of the same defile, from Clifton to Sea-mills.

PLATE XXXIV.

Fig. 1. is an enlarged section of the southernmost part of the defile of Clifton, exhibiting the great fault which traverses it to the north of St. Vincent's rocks.

Fig. 2. represents a section passing north and south from Brecon to the Bristol Channel across the coal basin of South Wales.

Fig. 3. represents an enlarged section of the southernmost part of fig. 2.

PLATE XXXV.

Fig. 1. represents the junction of the dolomitic conglomerate and old red sandstone on the left bank of the Avon opposite Sea-mills.

Fig. 2. represents the junction of the inferior oolite and mountain limestone, between Mells and Frome.

PLATE XXXVI.

Figs. 1 & 2. are sections of the pits marked A. B. and C., in the ground plan of Goodeave's colliery near Frome, drawn in the figure at the top of the plate.

PLATE XXXVII.

Fig. 1. represents a section of Aust cliff on the Severn, drawn along the line of the drift of the strata.

Figs. 2 & 3. are enlarged representations of the faults marked 1 and 2 in fig. 1.

Fig. 4. is a section of Aust cliff, drawn along the line of the dip of the strata.

PLATE XXXVIII.

Is a geological Map of the coal basins of Bristol and the Forest of Dean, and of the country bordering upon them.

PLATE XXXIX.

Map, Sketch, and Sections, in illustration of Mr. Weaver's paper on part of Gloucestershire and Somersetshire: pp. 318—368.

Fig. 1. Geological Map of the environs of Tortworth.

Fig. 2. A sketch of the north-western part of Cullimore's trap quarry: p. 334.

1. Stratified beds of sandstone, clay, marl, and limestone. 2. A mass of trap three feet thick. 3. A layer of sandstone, slate-clay, and other substances. 4. Trap four feet thick. 5. A layer analogous to No. 3. 6. Continuous trap.

Section 1.—On the line A B of the map.

Section 2.—On the line C D of the map.

Section 3.—On the line E F of the map.

Section 4.—From the Forest of Dean to the east of Huntley in Gloucestershire: p. 354.

Section 5.—From the river Parret, in Somersetshire, to the Avon near Bristol : p. 357.

A few objects which do not stand immediately in the line of this section, are projected upon it.

The small section beneath, represents, on the same scales, the position of the conglomerate &c. in the vicinity of Shipham, on a line parallel to that of section No. 5, and to the north-west of it: see p. 363.

PLATE XL.

No. 1. Inside view of the anterior portion of the lower jaw of the Megalosaurus on the right side. This drawing is of the actual size of the specimen.

No. 2. Transverse section of *No.* 1, showing the manner in which the tooth is lodged in the lower jaw.

PLATE XLI.

Fig. 1. is the same as Pl. XL., fig. 1., reduced to half the actual size.

Fig. 2. Outside view of *No.* 1.

Fig. 3. The same as *No.* 2, Pl. XL., reduced to half the actual size.

Fig. 4. A tooth, showing by the dotted lines the height to which the internal cavity rises.

Fig. 5. Upper portion of a nearly full grown tooth of the natural size ; its lower edges are very thin, and the root is not yet formed.

PLATE XLII.

Fig. 1. Five anchylosed vertebræ, including the sacral portion of the column.

Fig. 2. Single lumbar vertebra.

Fig. 3. Single caudal vertebra.

Fig. 4. View of the articulating surface of *No.* 2, much reduced in size. It has been a little distorted by pressure.

PLATE XLIII.

Fig. 1. Upper portion of a rib, showing it to have had a double head of articulation. Its transverse section is given at the two fractured parts *a* & *b*.

Fig. 2. Small false rib, showing the same double head of articulation as in fig. 1.

Fig. 3. Exterior view of the Os ilium.

Fig. 4. Os pubis of a very small individual. By the side of fig. 4. at *a*, is represented the transverse section of its flat extremity.

Fig. 5. Fragment of a bone, probably the ischium, extremely solid throughout.

Fig. 6. Fragment of a flat bone nearly two inches thick, probably part of a scapula.

PLATE XLIV.

Figs. 1 & 2. Two opposite views of the largest femur of Megalosaurus in the Oxford Museum.

Figs. 3 & 4. Two views of probably a clavicle of ditto.

Fig. 5. Portion of a long and slender bone, apparently a fibula.

Fig. 6. Posterior portion of a large bone, either of the Metacarpus or Metatarsus.

PLATE XLV.

Represents different portions of Clathraria anomala reduced.

PLATE XLVI.

Represents Endogenites erosa reduced, Carpolithus (   ) Mantellii, Hymenopteris psilotoides, and Pecopteris reticulata, of their natural size.

PLATE XLVII.

Fig. 1. *a* and *b*. C. Mantellii magnified to show the markings on its surface.

Fig. 2. Hymenopteris psilotoides magnified to show the decurrent membrane connecting the pinnæ.

Fig. 3. Pecopteris reticulata, a portion magnified to show the veins.

Fig. 4. *a*. A portion of the outer covering of Clathraria anomala, natural size.

Fig. 4. *b*. Inner portion of the same with a cicatrix.

Fig. 4. *c*. A termination of the same, and showing the imbrications of its surface.

Fig. 4. *d*. A portion of the same, showing the cellular body intervening between the external and internal body.

Fig. 5. *a*. A portion of the exterior of Endogenites erosa magnified.

Fig. 5. *b*. Transverse section of the same magnified.

EXPLANATION OF THE PLATES.

PLATE XLVII.

Represents the crag resting upon chalk, as it actually appears in Bramerton Cliff near Norwich.

PLATE XLVIII.

This plate contains a representation of a nearly perfect skeleton of the Plesiosaurus dolichodeirus, described page 381 of this volume. The drawing has been executed with extreme care by Mr. Webster. The several parts are described in the accompanying memoir.

The bones are entirely imbedded in a matrix of lias shale, which, though intersected in several places by lines of fracture, has evidently, from the mutual adaptation of the parts, formed one entire mass. Above 20 of the cervical vertebræ connected with the head, lie together unbroken.

We have omitted to state in the memoir, that a second unbroken specimen of the entire vertebral column, from the head to the tail, was found at the same time and place with the one here represented; and has been presented by Professor Buckland to the Museum at Oxford.

PLATE XLIX.

Restoration of the Plesiosaurus dolichodeirus and Ichthyosaurus communis.

Fig. 1. Skeleton of the Plesiosaurus dolichodeirus restored, on the authority of the specimen in the preceding plate; the humero-sternal portion being supplied from a specimen in the Oxford collection.

Fig. 2. The humero-sternal portion as above: see the description in the memoir.

Fig. 3. Sterno-costal arcs.

Fig. 4. The pelvis.

Fig. 5. The humero-sternal portion of the Ichthyosaurus communis, from two nearly perfect specimens in the Oxford collection, collated with a third belonging to H. T. De la Beche, Esq., all agreeing exactly together.

Fig. 6. Skeleton of the Ichthyosaurus communis, restored from a very perfect specimen in the collection of the Bristol Institution.

Fig. 1.

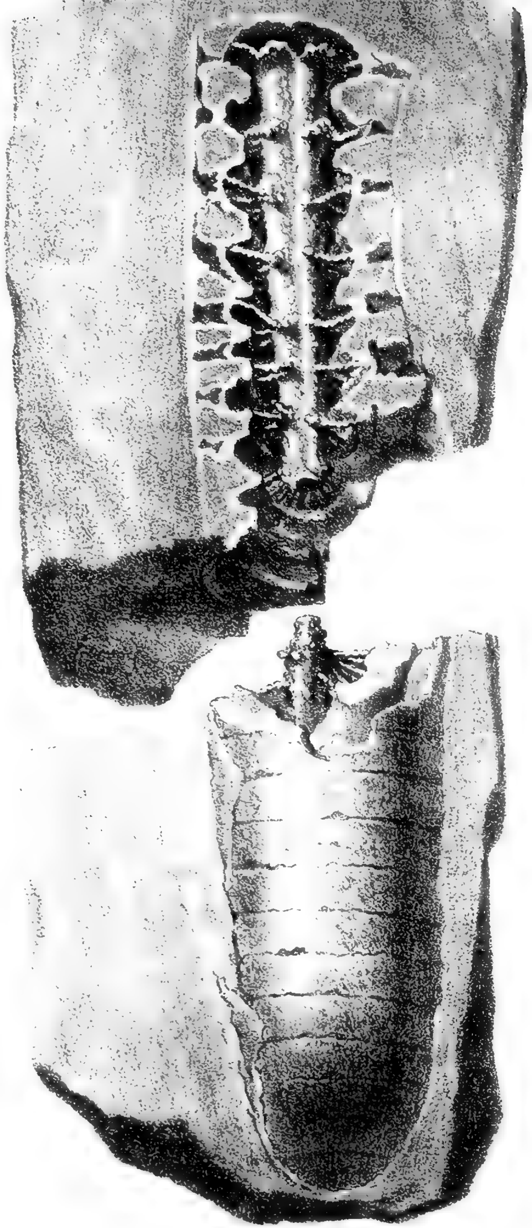


Fig. 2.

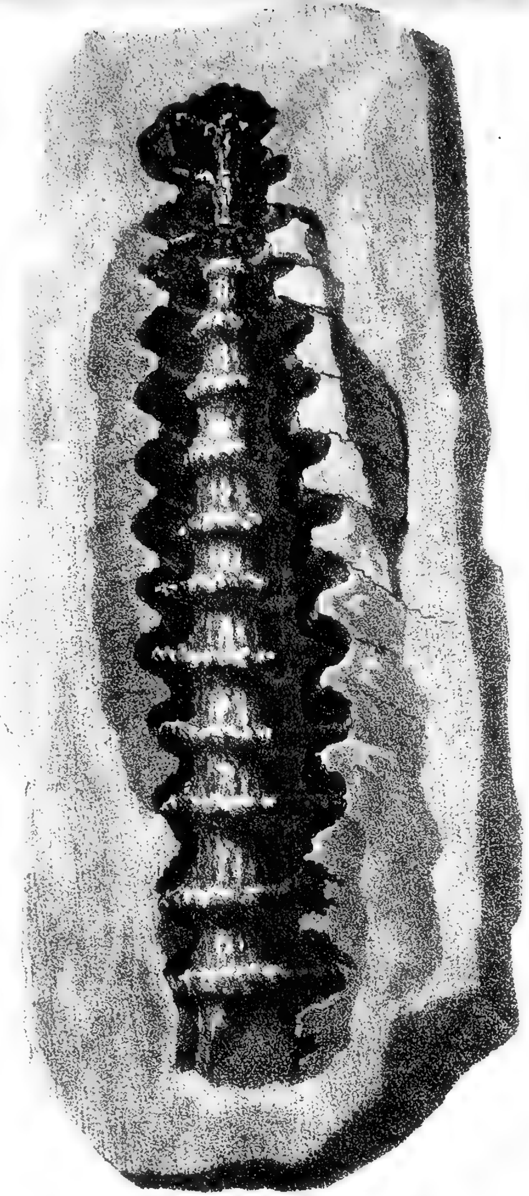
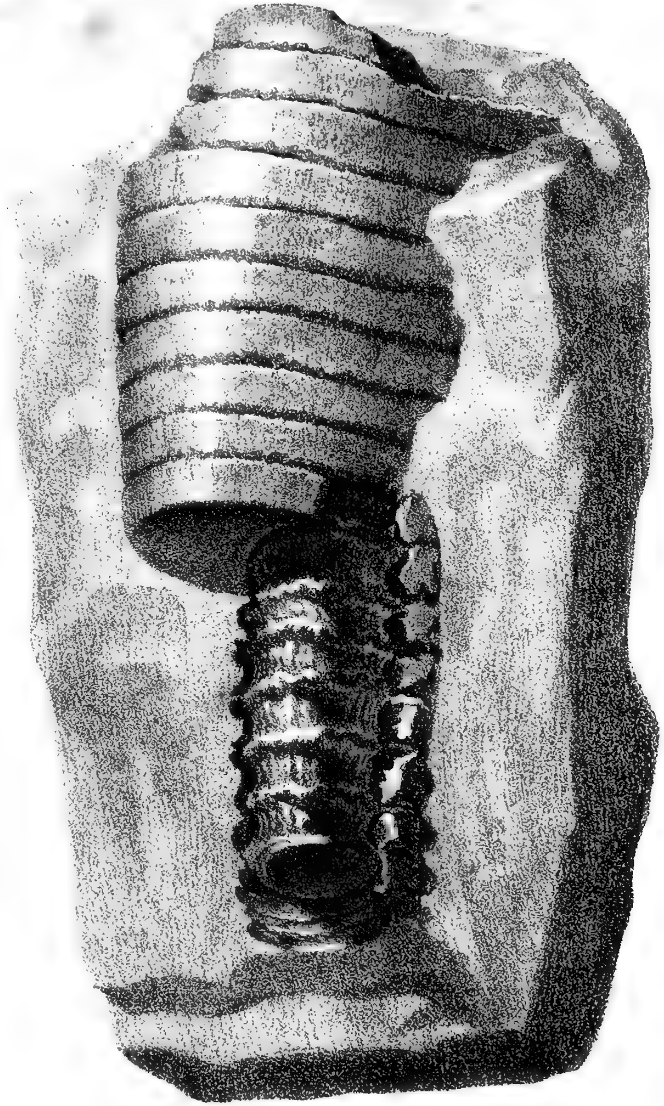


Fig. 3.



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FOSSIL ORTHOCERAE.

FROM THESSALON ISLAND. LAKE HURON.

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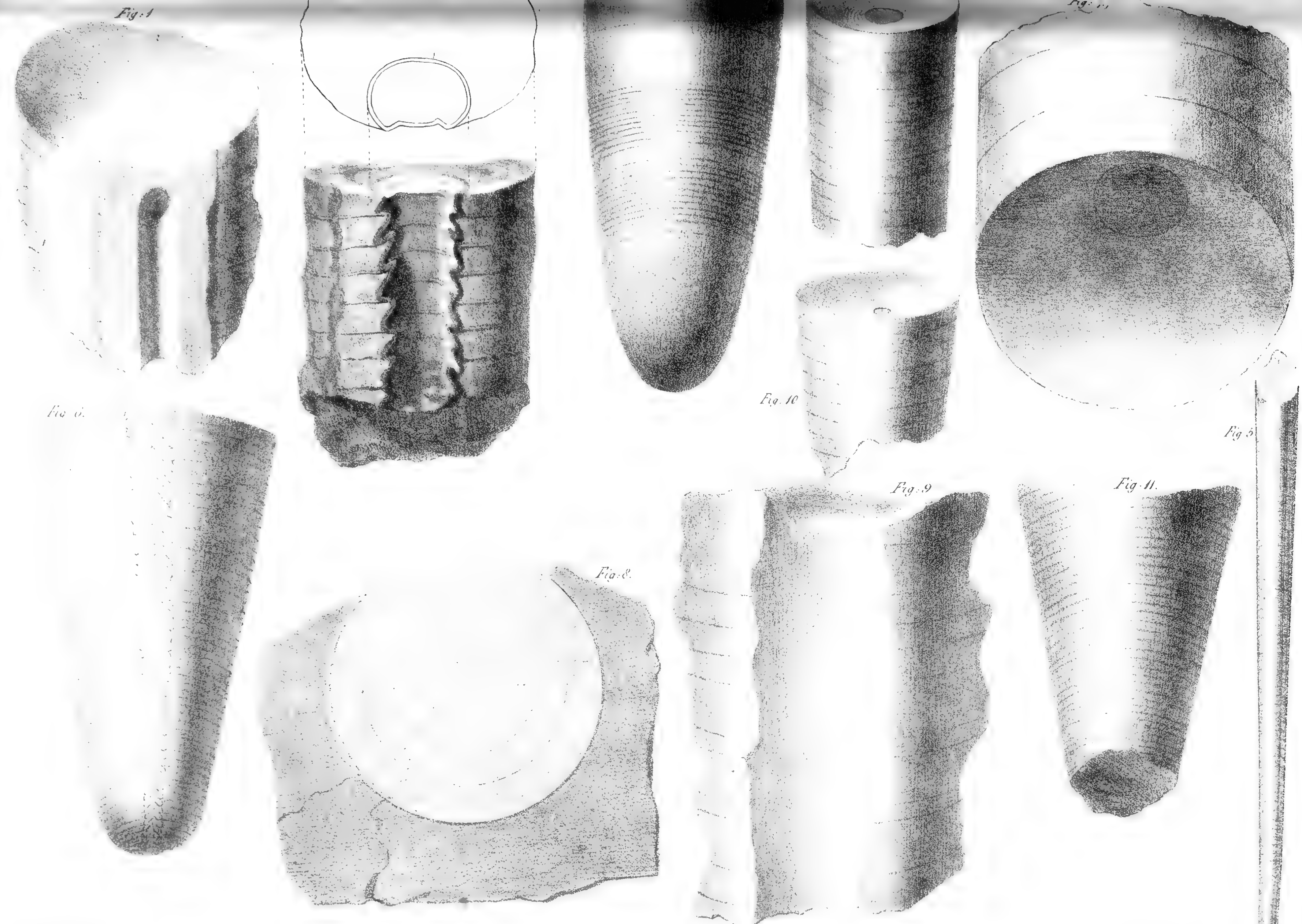

G. Scharf lithog.

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Fig. 1. a.

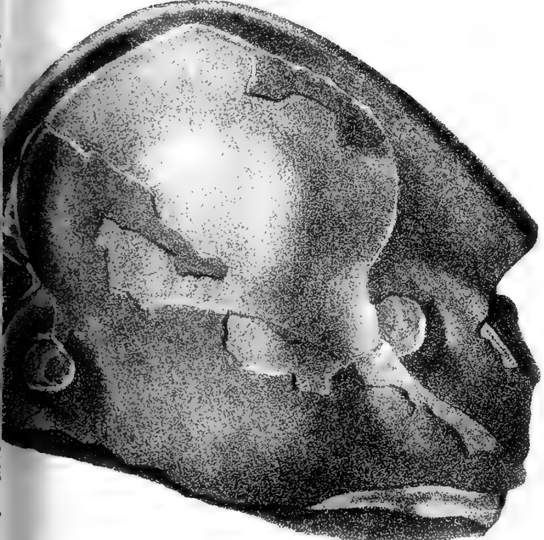


Fig. 1. b.

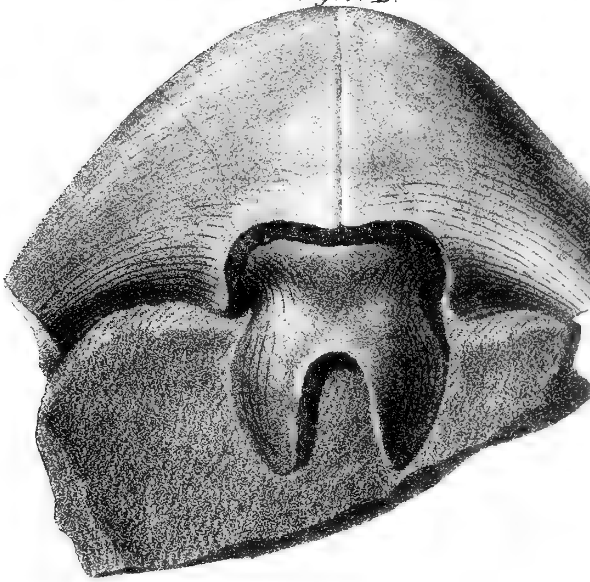


Fig. 1 c

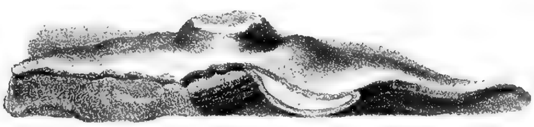
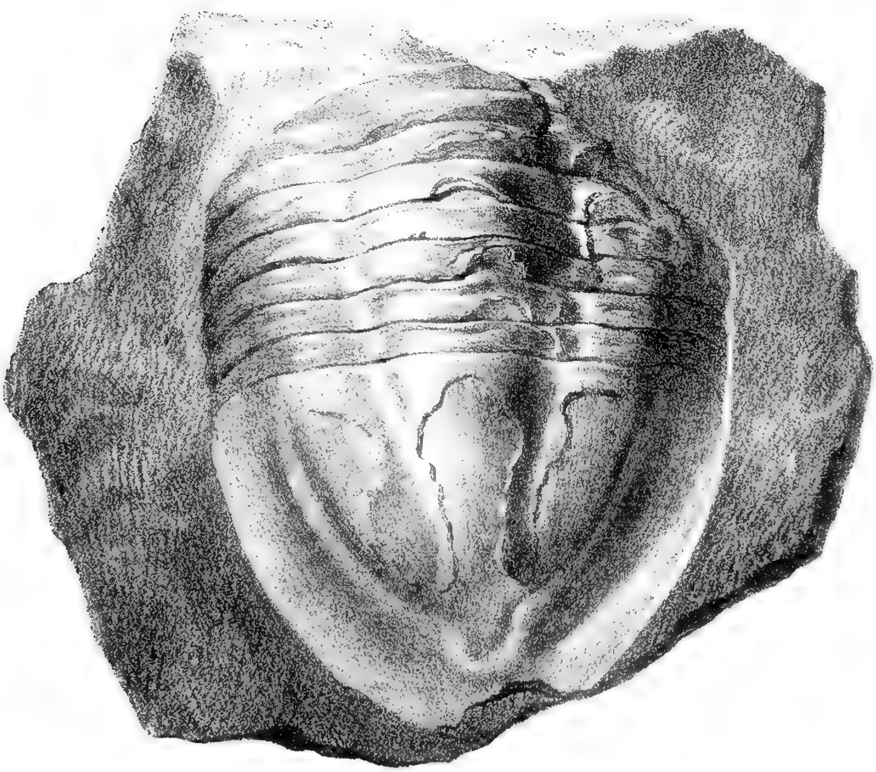


Fig 2



G. Scharf del et Lithog

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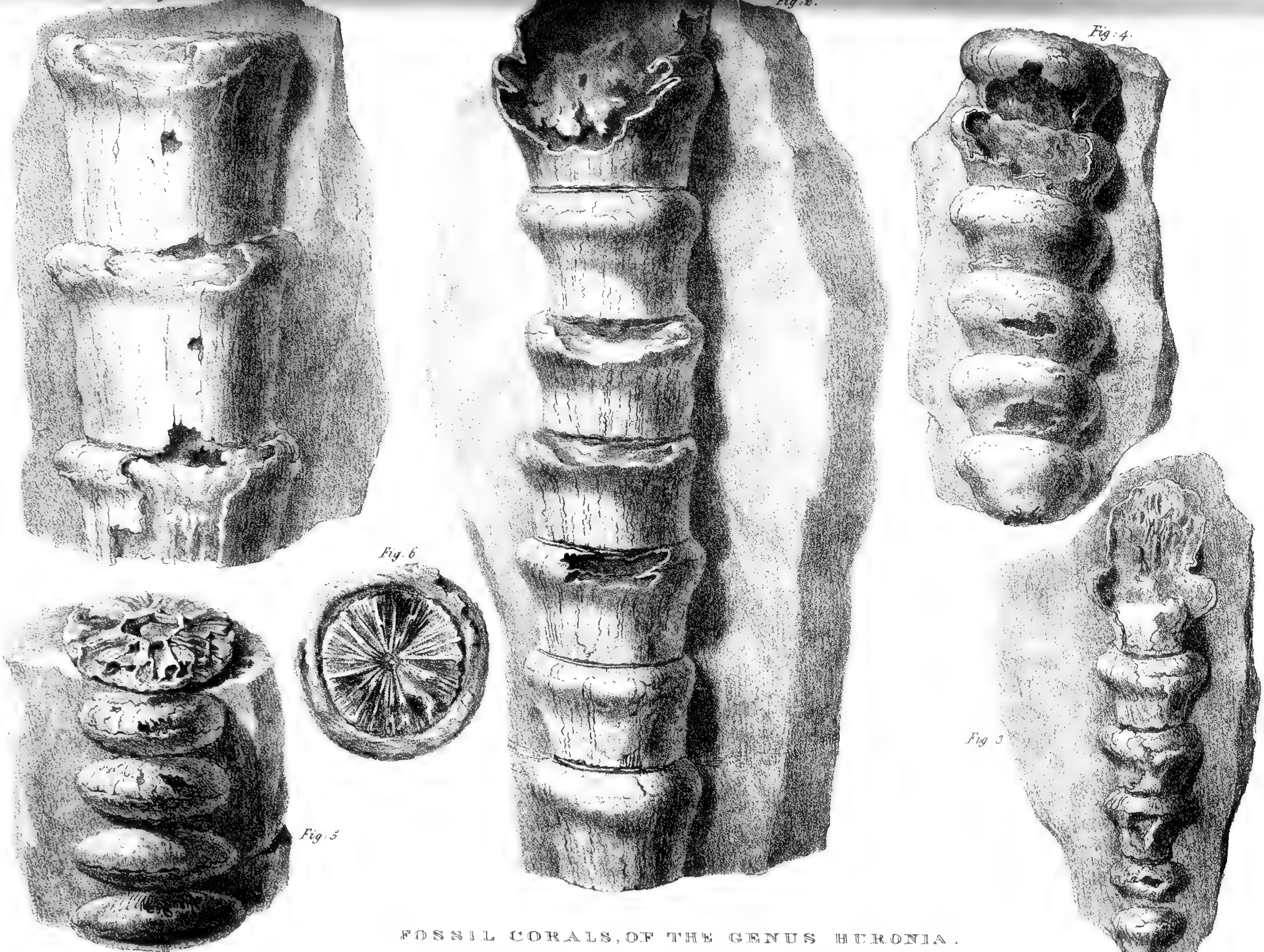
ASAPHUS PLATYCEPHALUS.

FROM St JOSEPH'S ISLAND .. LAKE HURON



G. Scharf del. et lithog.

FOSSIL CORALS, OF THE GENUS HURONIA.

FROM DRUMMOND ISLAND, LAKE HURON.

Fig. 1.

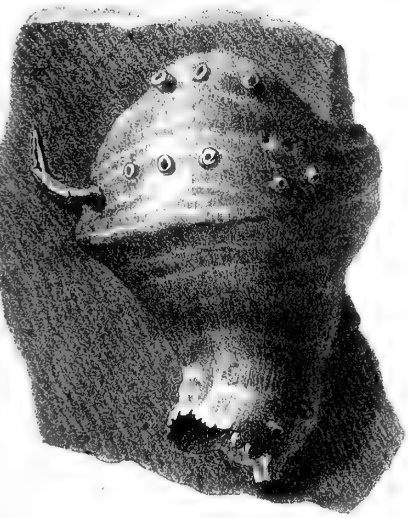


Fig 1.

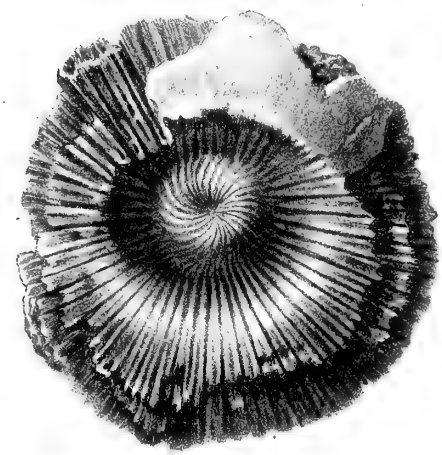


Fig 2. a.

Fig 2. b.

Fig. 6

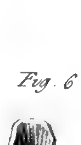


Fig. 5

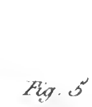


Fig 3.

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FOSSIL CORALS FROM DRUMMOND ISLAND.
LAKE HURON.

Fig. 1

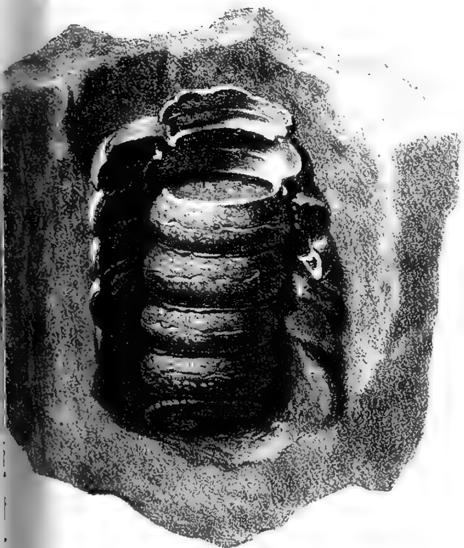


Fig. 2

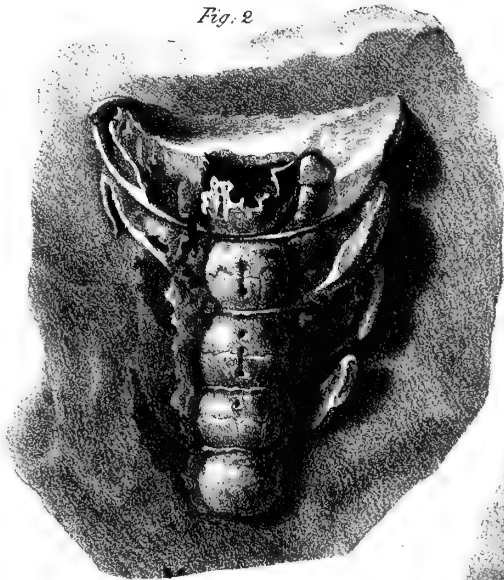


Fig. 3.

Fig. 4.

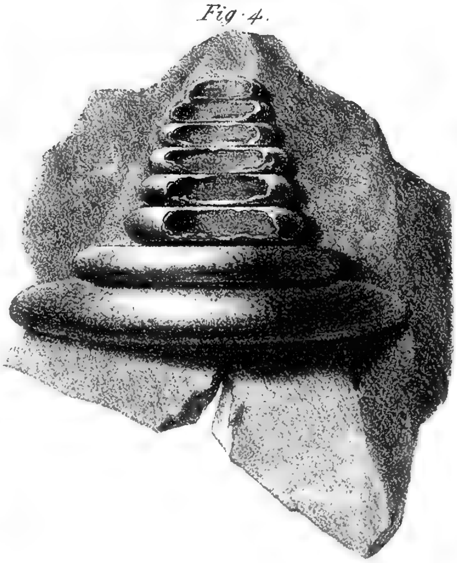


Fig. 5

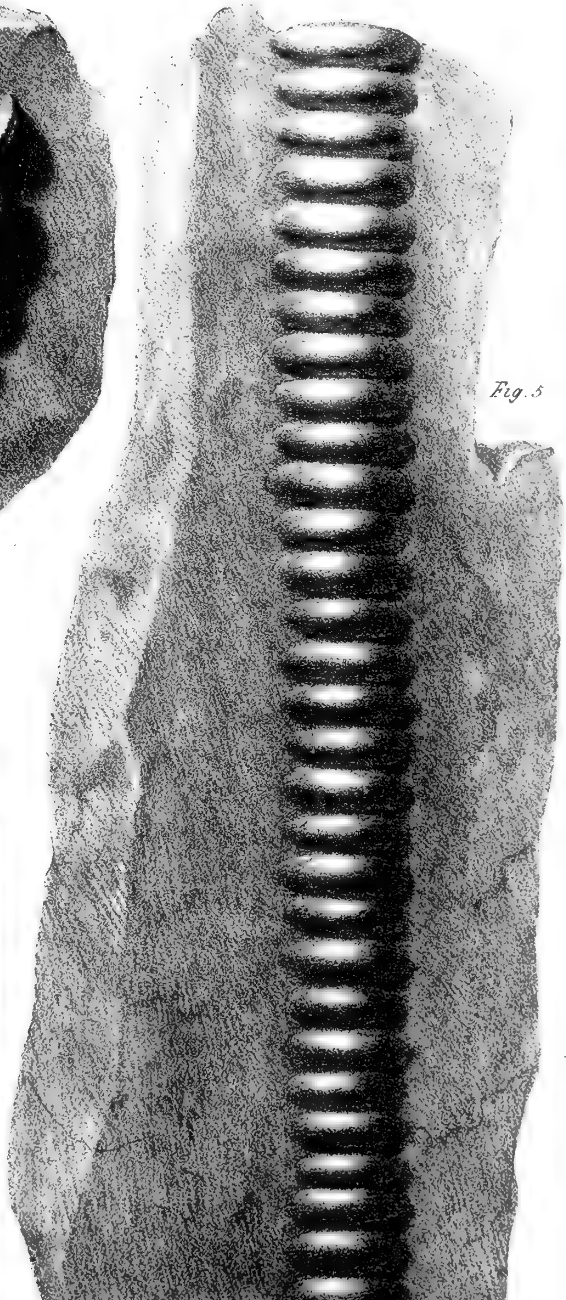


Fig. 6

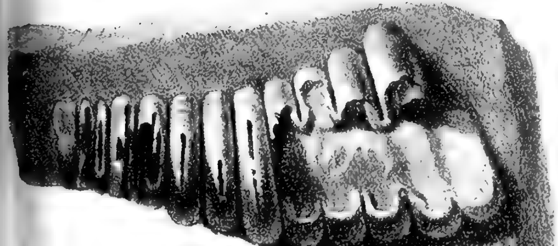
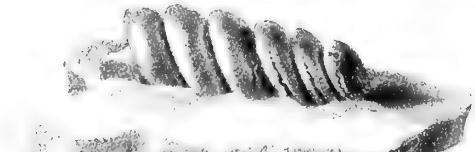


Fig. 7



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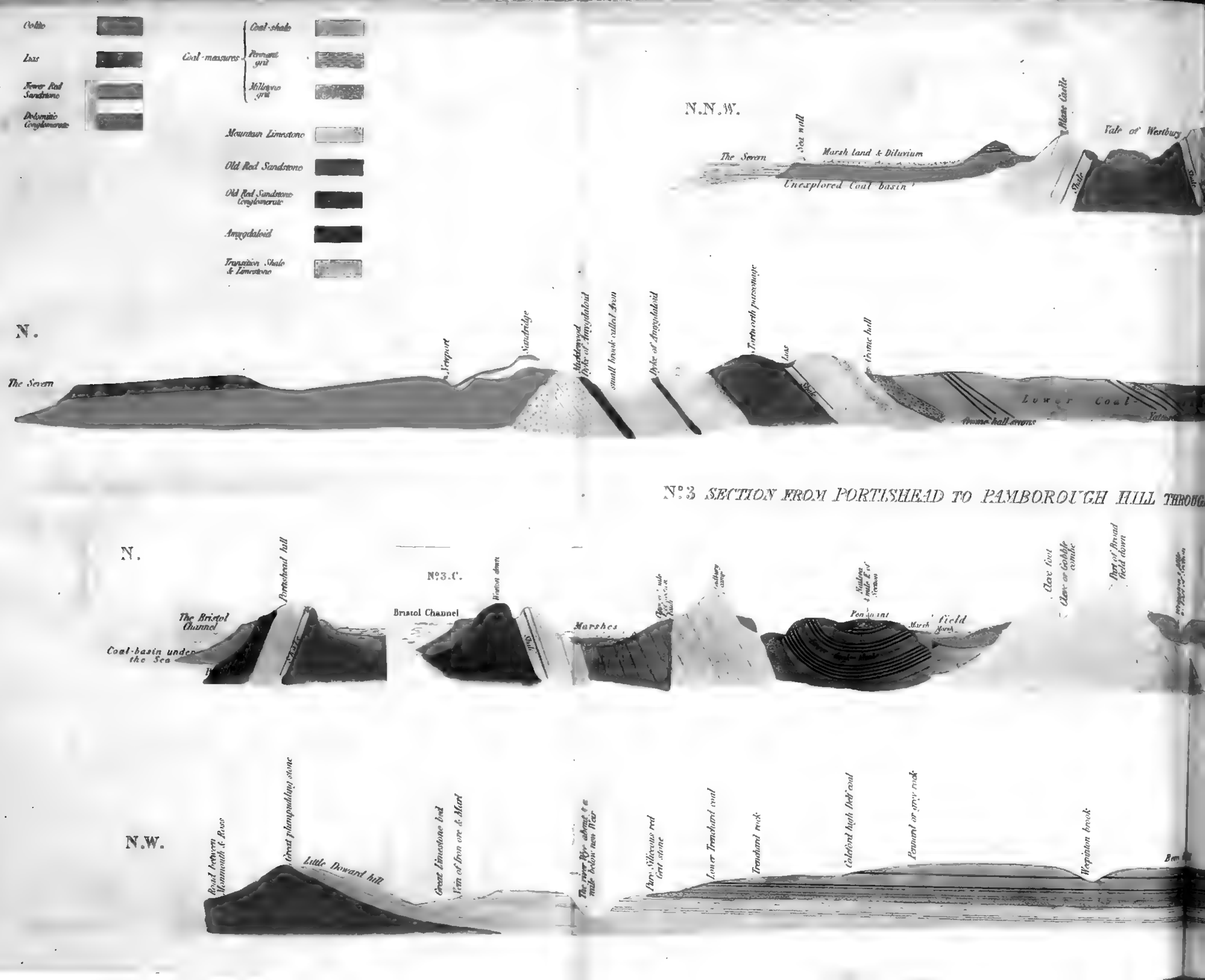
FOSSILS, FROM DRUMMOND ISLAND.


UPPER CANADA
LAKE HURON
LAKE MICHIGAN
UNITED STATES
MICHIGAN TERRITORY
GEORGIAN BAY
UPPER CANADA
St. Joseph
Sugar Island
I. Thessalon
Le Serpent
La Cloche
Hill Islands
Drummond
Little Manitou
Grand Manitou
Martin's Isl.
Straits of Michilimackinac
Bois-blanc Island
Point Colles
French River
Fourth Manitou
Shingle Bank
Snake's Head
Bear's Rump
Flower Pots
Isle of Coves
Cape Hurd
Cabot's Head
Point Wingfield
THUNDER BAY
GLOUCESTER
MATCHEDASH BAY
IROQUOIS BAY
Presqu'isle
Middle Islands
Thunder River
THUNDER BAY
GULF OF SAGUINA
Point aux Barques
White Rock
R. Saguina
Boundary Line between Upper Canada and The United States
Ft. Gratiot
Map to accompany
Dr. BIGSBY'S PAPER
ON
the Geography and Geology of
LAKE HURON.
J. J. Bigsby del.
C. Hullmandel's Lithography


Oolite
Lias
Lower Red Sandstone
Dolomitic Conglomerate
Coal-measures
Coal-shale
Pennant grit
Millstone grit
Mountain Limestone
Old Red Sandstone
Old Red Sandstone Conglomerate
Amygdaloid
Transition Shale & Limestone
N.N.W.
The Severn
Sea wall
Marsh land & Diluvium
Unexplored Coal basin
Blaise Castle
Vale of Westbury
Shale
N.
The Severn
Newport
Sandridge
small brook called Avon
Dyke of Amygdaloid
Tortworth parsonage
Lias
Shale
Cromo hall
Lower Coal-
N°3 SECTION FROM PORTISHEAD TO PAMBOROUGH HILL THROUGH
N.
Portishead hill
N°3.C.
Weston down
The Bristol Channel
Coal-basin under the Sea
Bristol Channel
Shale
Marshes
Pennant
Marsh
field
Cleve toot
Cleve or Goblin combe
Part of Broad field down
N.W.
Road between Monmouth & Ross
Great plumpudding stone
Little Doward hill
Great Limestone bed
Vein of Iron ore & Marl
The river Wye about ¼ a mile below new Weir
Pure Siliceous red Grit stone
Lower Trenchard coal
Trenchard rock
Coleford high Delf coal
Pennant or grey rock
Werpiston brook

No.1 SECTION OF THE BRISTOL COAL-BASIN FROM N.N.W. TO S.S.E. CROSSING No.2 NEAR BARROW HILL.
Dundry hill
Barrow hill
The 7 Northern seams
The 7 Northern seams
Faringdon seams
Upper coal-shale
Probable continuation of the Pennant
No.1.B
No.1.C
Mendip hills
S.S.E.
No.2 SECTION OF THE BRISTOL COAL-BASIN ALONG ITS GREATEST DIAMETER FROM NORTH TO SOUTH.
Coal pit heath
Upper coal shale
Undulating
No.2.B.
Barrow hill
The 7 Northern seams
Upper coal-shale
probable continuation of the Pennant
Pennant
Farrington seams
No.2.A
Mendip hills
Marsh
S.
N.3.A.
No.3.B.
Coal-measur
marsh
marsh
marsh
S.
No.4 SECTION OF THE BRISTOL COAL-FIELD FROM EAST TO WEST.
W.
Unexplored Coal-basin
Mangotsfield Common
Cock & Hen coal veins
Dip N.
Pennant
Lower Coal shale
red sand stone
E.
No.5 SECTION OF THE BASIN OF THE FOREST OF DEAN BETWEEN THE RIVERS WYE & SEVERN FROM N.W. TO S.E. SCALE ONE INCH TO 240 FATHOMS.
by David Mushet Esqr. of Coleford
Sparrow hill
Bixslade hill
Centre of the basin
S.E.
Thos. Bradley sculp.

H. T. De la Beche del.

GEOLOGICAL MAP of the COURSE OF THE AVON, from CLIFTON to HUNGROAD.

H. T. De la Beche del.

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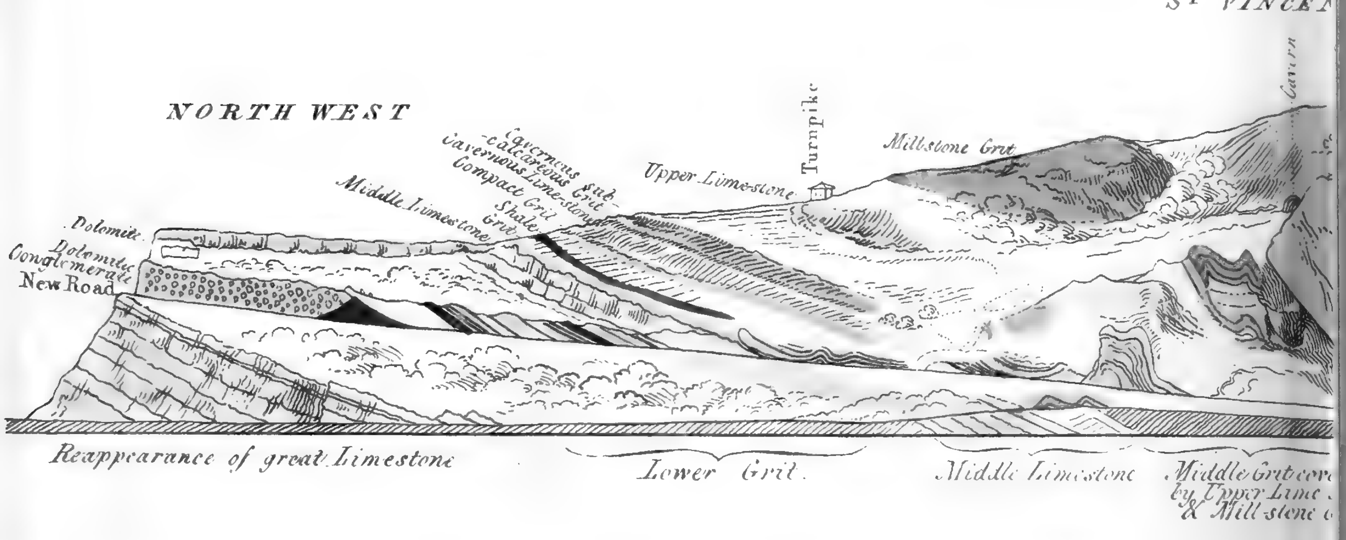
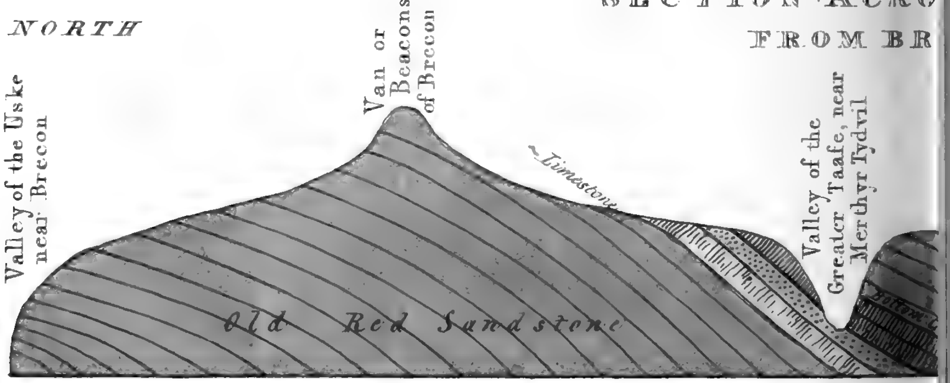
B. R. Baker Lithog.

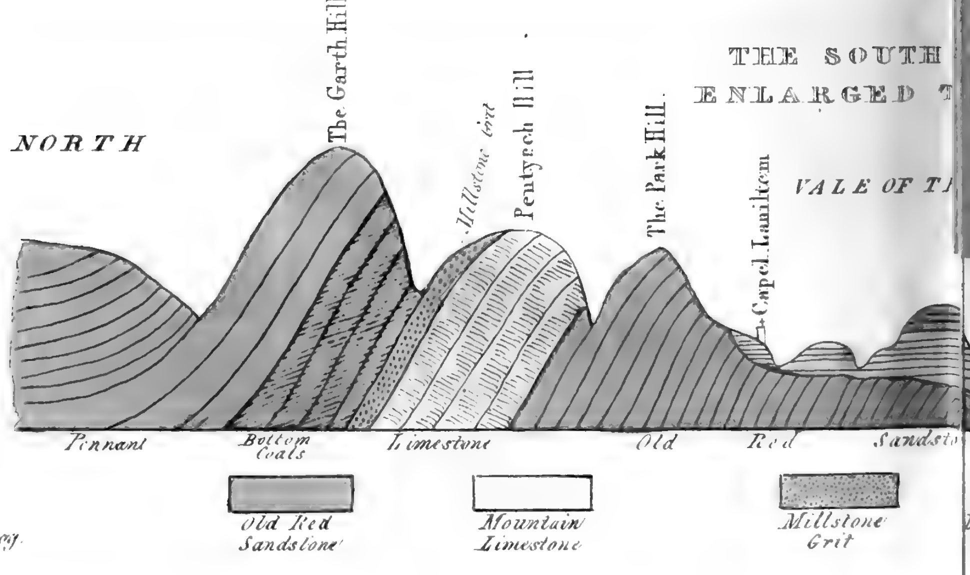
SECTION OF THE CLIFFS ON THE RIGHT BANK OF THE



SECTION ACRO
FROM BR

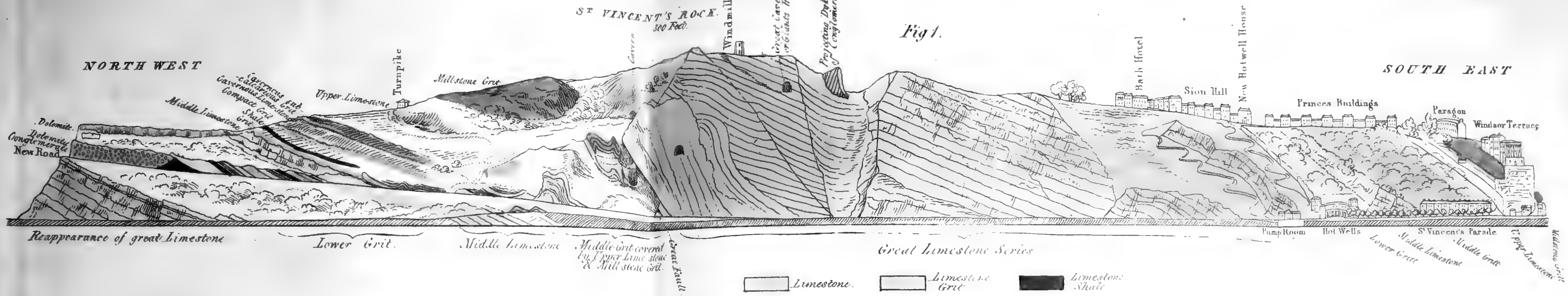


THE SOUTH
ENLARGED T

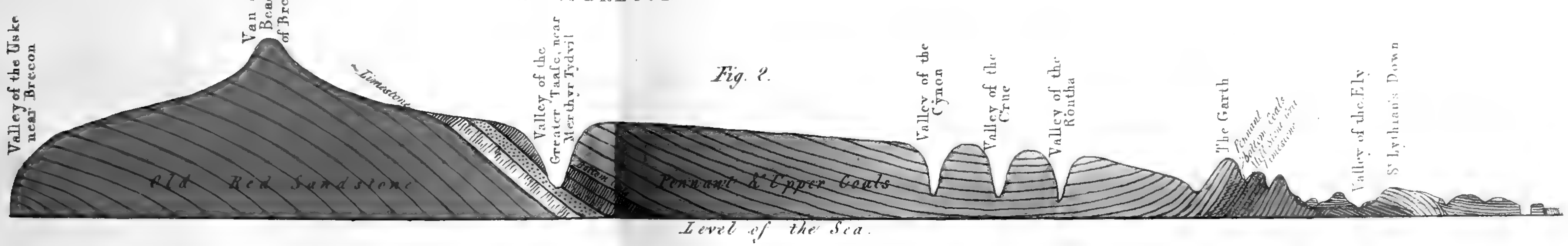


G. Scharf Lithog.

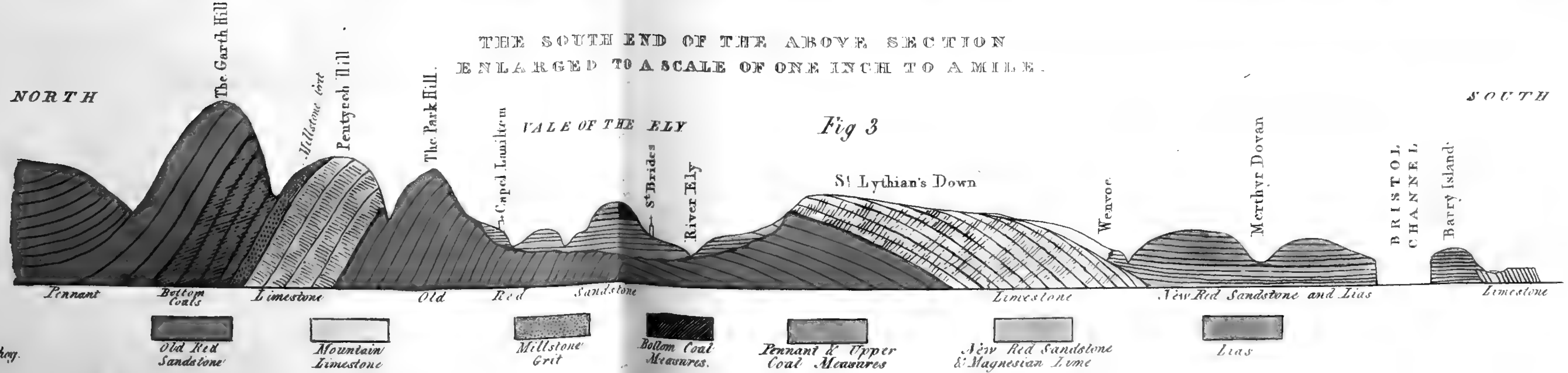
SECTION OF THE CLIFFS ON THE RIGHT BANK OF THE AVON AT THE SOUTH EASTERN EXTREMITY OF THE CLIFTON DEFILE



SECTION ACROSS THE SOUTH WELSH MINERAL BASIN FROM BRECON TO THE BRISTOL CHANNEL



THE SOUTH END OF THE ABOVE SECTION ENLARGED TO A SCALE OF ONE INCH TO A MILE.



G. Scharf Lithog.

Printed by C. Hullmandel

Junction on the Left Bank of the Avon opposite to Sea Mills.

Old Red Sandstone

Dolomitic Conglomerate

Junction seen in a Quarry between Mells & Frome
on the Left Bank of the River

H.T. de la Beche del.t *G. Scharf Lithog.*

Mountain Limestone

Inferior Oolite

Printed by C. Hullmandel

Ground-Plan of Goodeaves Colliery, shewing the Position of the Pits.

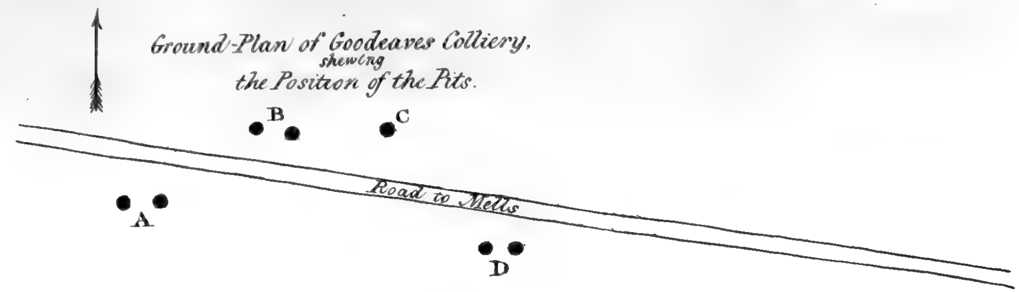


Fig: 1. Section of Goodeaves Pit

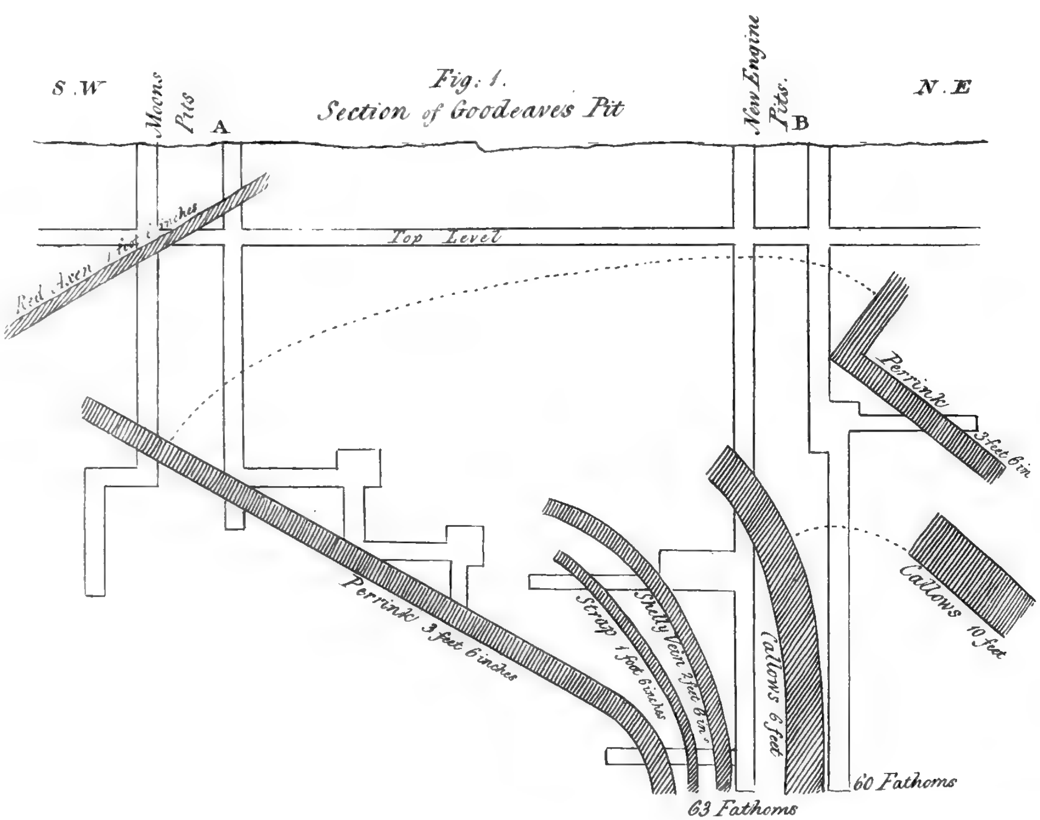
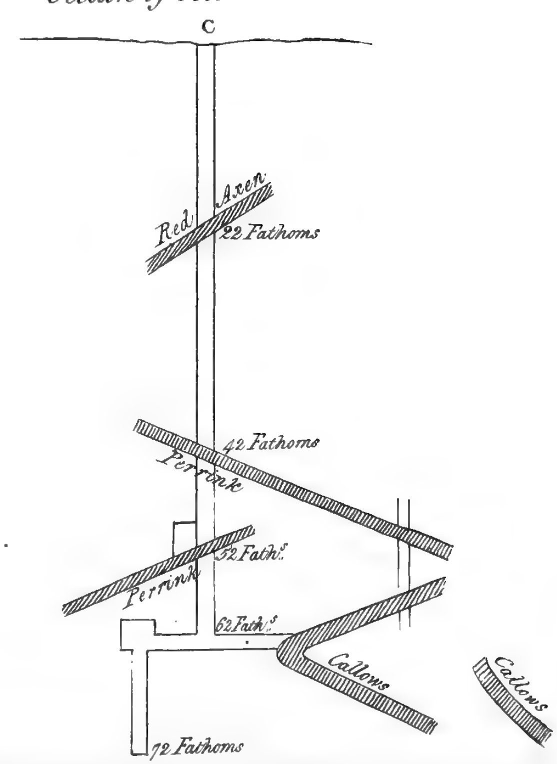


Fig: 2. Section of Goodeaves Pit



PLAN & SECTIONS OF GOODEAVES COLLIERY.

G. Scharf Lithog:

Printed by C. Hullmandel.

AUST CLIFF.

Fig: 1.

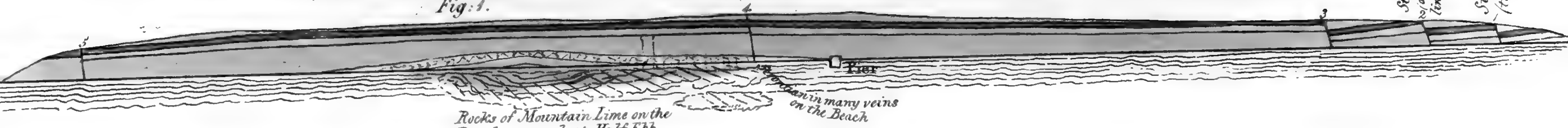
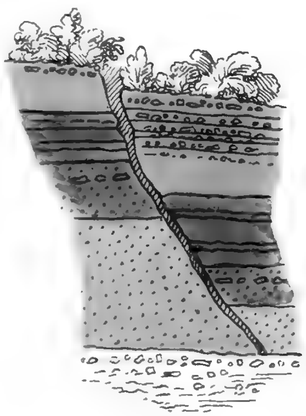
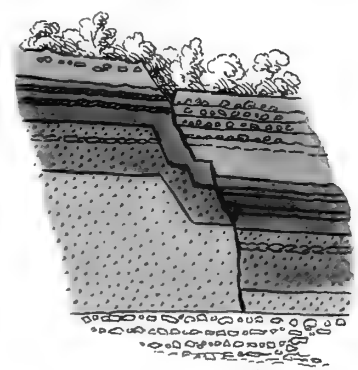


Fig: 2.



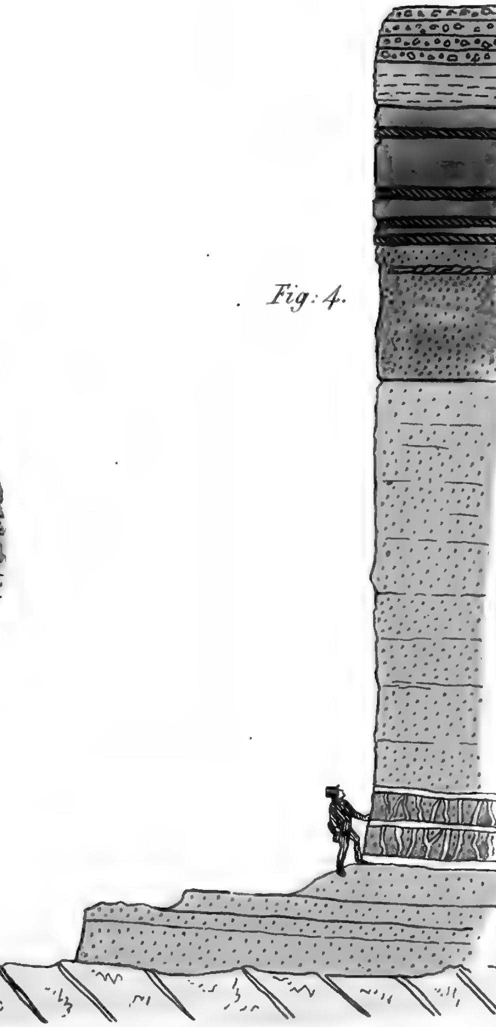
2d. Fault.
about 16 Feet

Fig: 3.



1st. Fault.
about 18 Feet

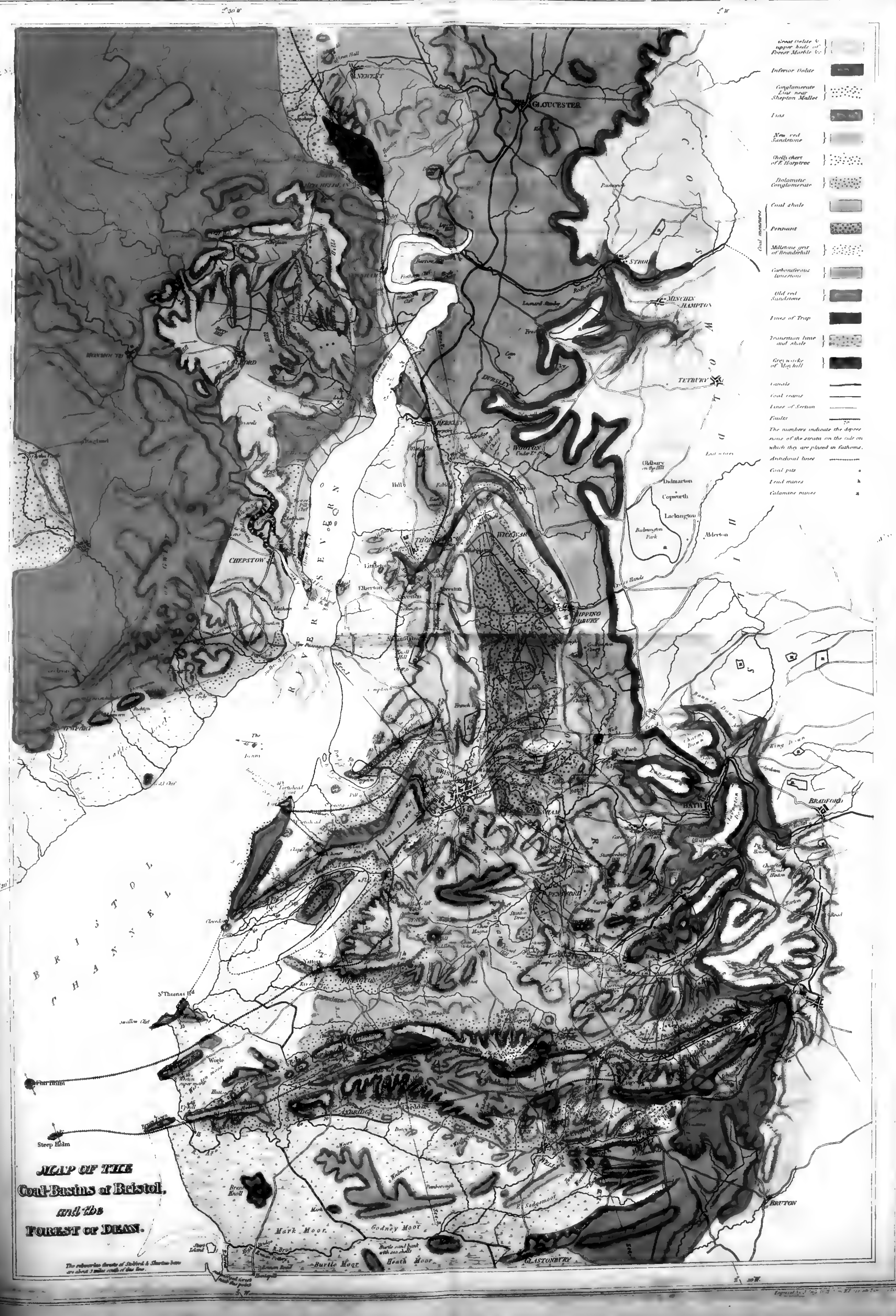
Fig: 4.

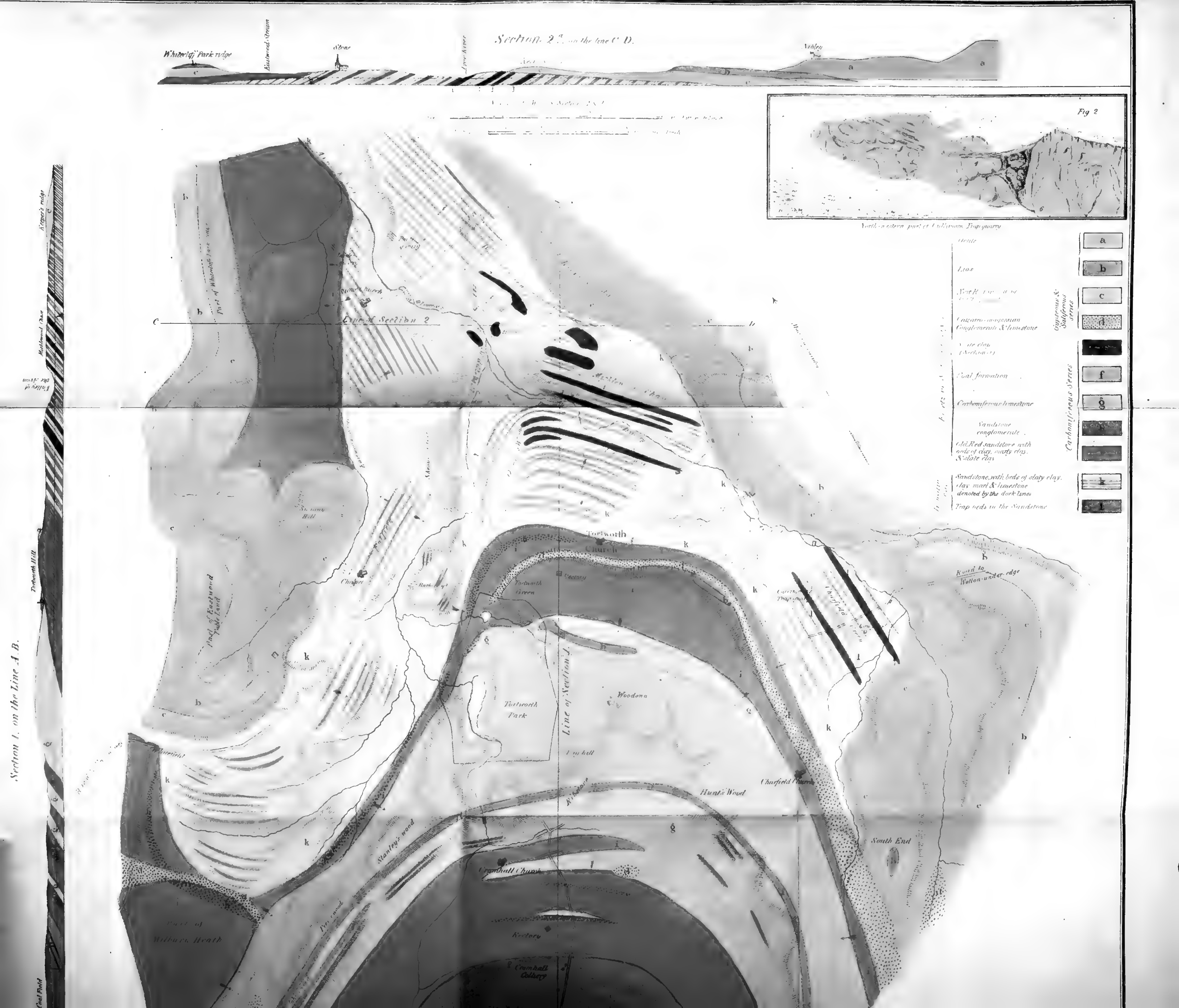


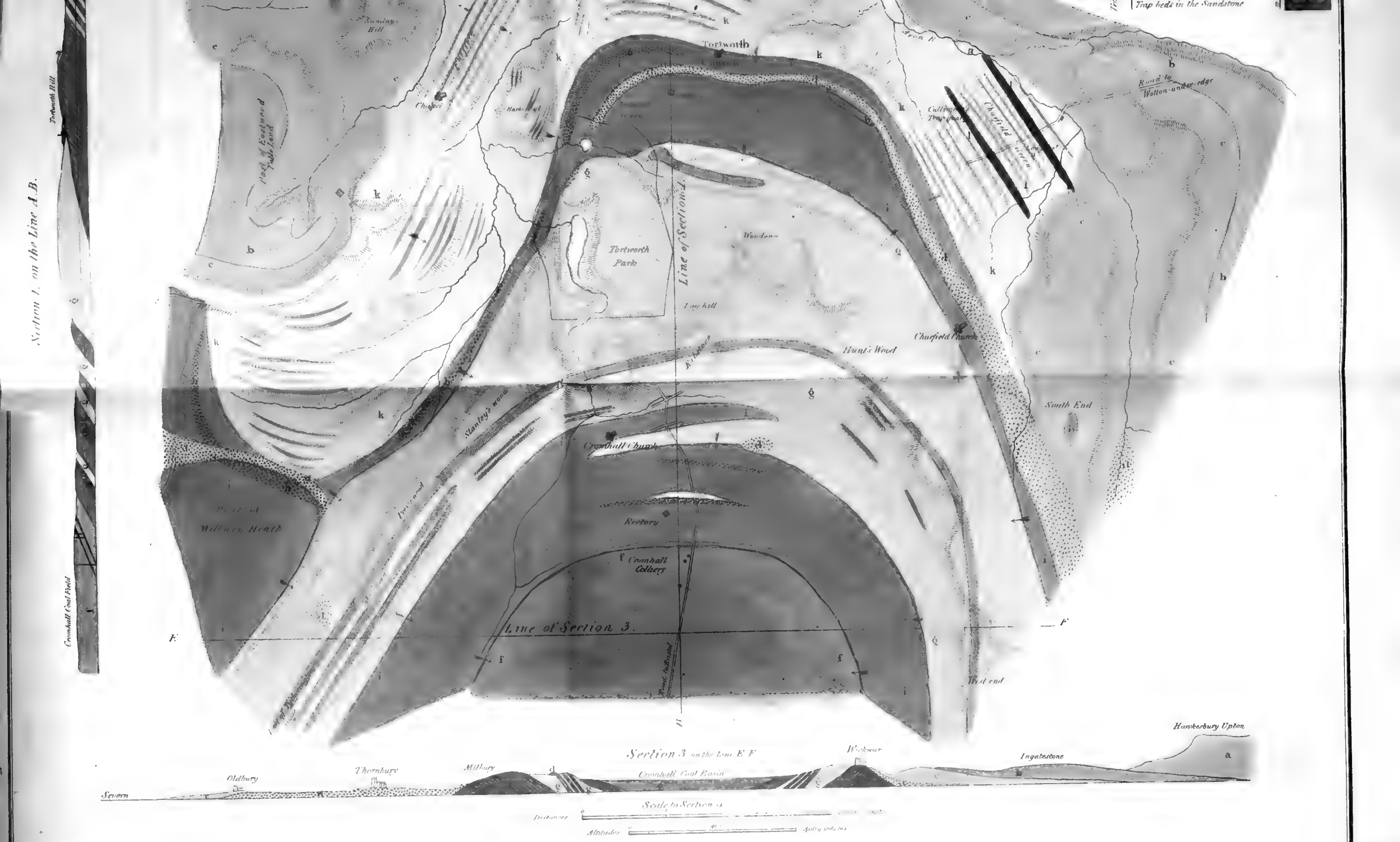
G. Scharf Lithog:

H.T. De la Beche Esqr. delt.

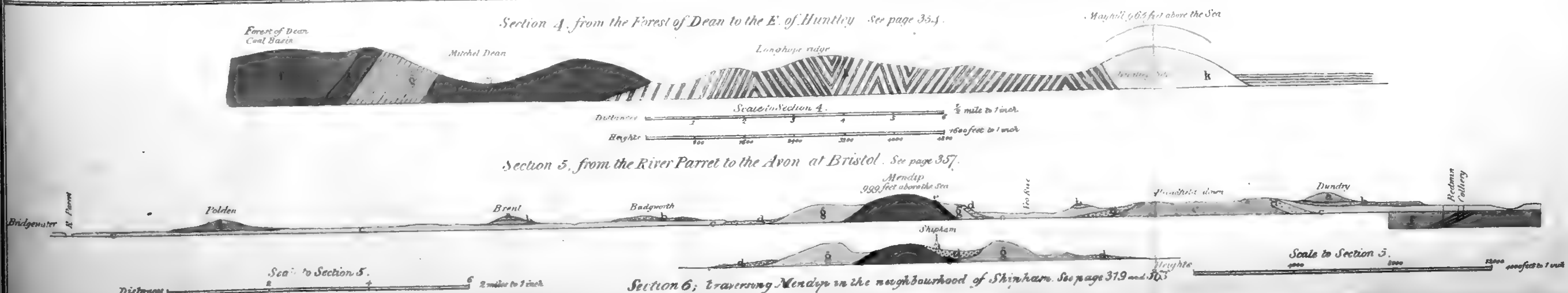
Printed by C. Hullmandel.


MAP OF THE
Coal-Basins of Bristol,
and the
FOREST OF DEAN.
Inferior Oolite
Conglomerate Lias near Shepton Mallet
New red Sandstone
Shelly chert of E. Harptree
Dolomitic Conglomerate
Coal measures
Coal shale
Pennant
Millstone grit of Brandonhill
Carboniferous limestone
Old red Sandstone
Lines of Trap
Transition lime and shale
Canals
Coal seams
Lines of Section
Faults
The numbers indicate the depressions of the strata on the side on which they are placed in fathoms.
Anticlinal lines
Coal pits
Lead mines
Calamine mines
GLOUCESTER
NEWENT
STROUD
MINCHIN HAMPTON
TETBURY
DURSLEY
BERKELEY
WOOTTON Under Edge
THORNBURY
WICKWAR
CHIPPING SODBURY
CHEPSTOW
MONMOUTH
NEWPORT
BRISTOL
BATH
BRADFORD
PENSFORD
GLASTONBURY
BRUTON
RIVER SEVERN
BRISTOL CHANNEL
Steep Holm
Clevedon
Yatton
St. Thomas Hd.
Oldbury on the Hill
Didmarton
Copworth
Lackington
Alderton
Badminton Park
Elberton
Olveston
Almondsbury
Dundry Hill
Brent Knoll
Mark Moor
Godney Moor
Burtle Moor
Heath Moor
Sedgemoor
Pawlett
Highbridge


Section 2d on the line C D.
Whitcliff Park ridge
Eastwood Stream
Stone
Fig 2
Lias
Calcareo-magnesian Conglomerate & limestone
Coal formation
Carboniferous limestone
Old Red sandstone with beds of clay, marly clay, & slate clay
Carboniferous Series
Sandstone with beds of slaty clay, clay marl & limestone denoted by the dark lines
Trap beds in the Sandstone
Line of Section 2
Part of Whitcliff Park
Tortworth Church
Tortworth Green
Tortworth Park
Line of Section 1
Woodend
Road to Wotton-under-edge
Charfield Church
Hunt's Wood
South End
Stanley's wood
Cromhall Church
Rectory
Cromhall Colliery
Part of Eastwood Table land
Section 1. on the Line A.B.
Tortworth Hill
Coal Field



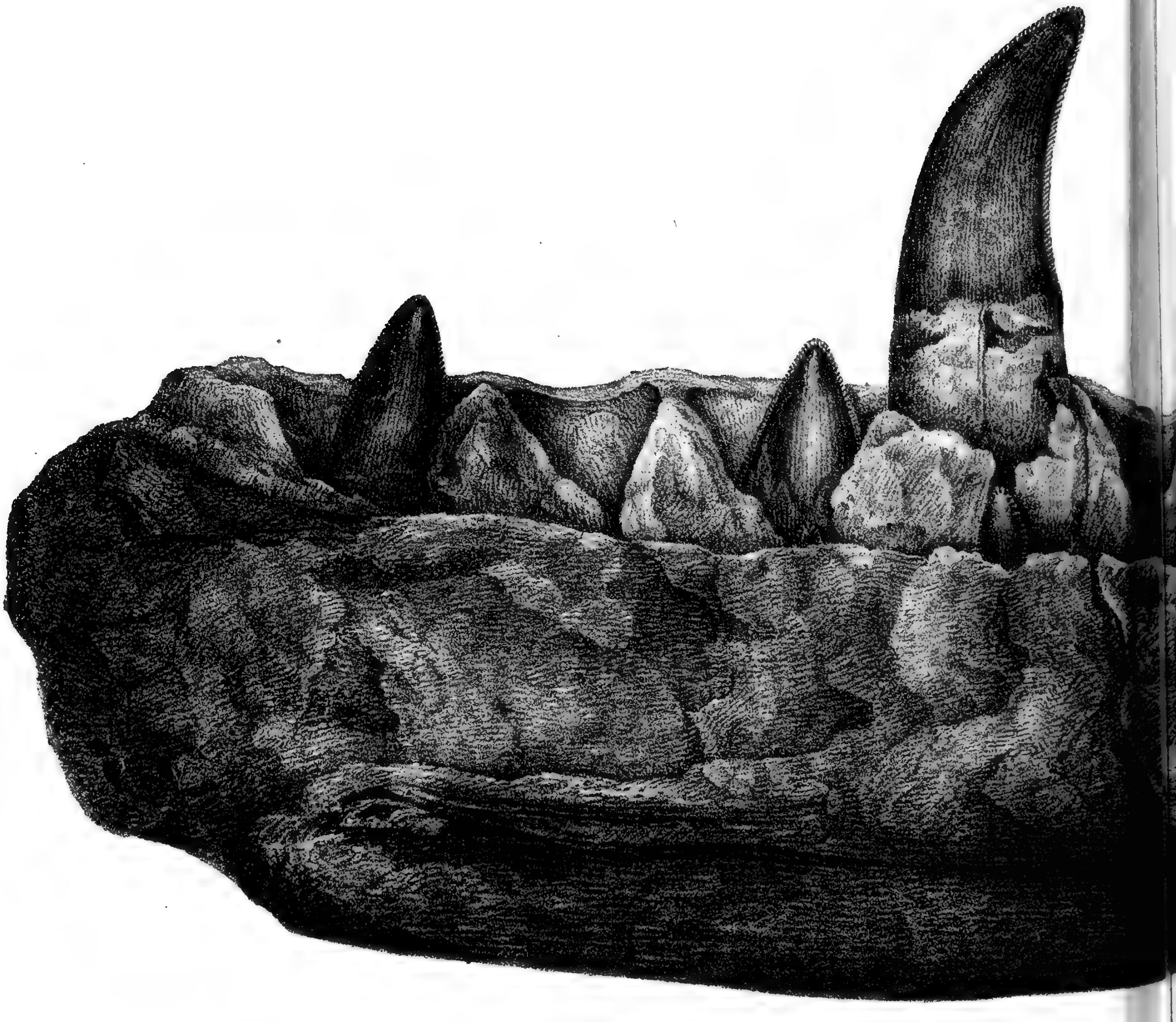
GEOLOGICAL MAP & SECTIONS of the ENVIRONS of TORTWORTH, GLOCESTER.



Drawn by T. Weaver

Printed by S. Bruckwood

B. R. Baker Lithog.



ANTERIOR EXTREMITY OF THE RIGHT

FROM STONESFIELD

1 2 3 4 5 6

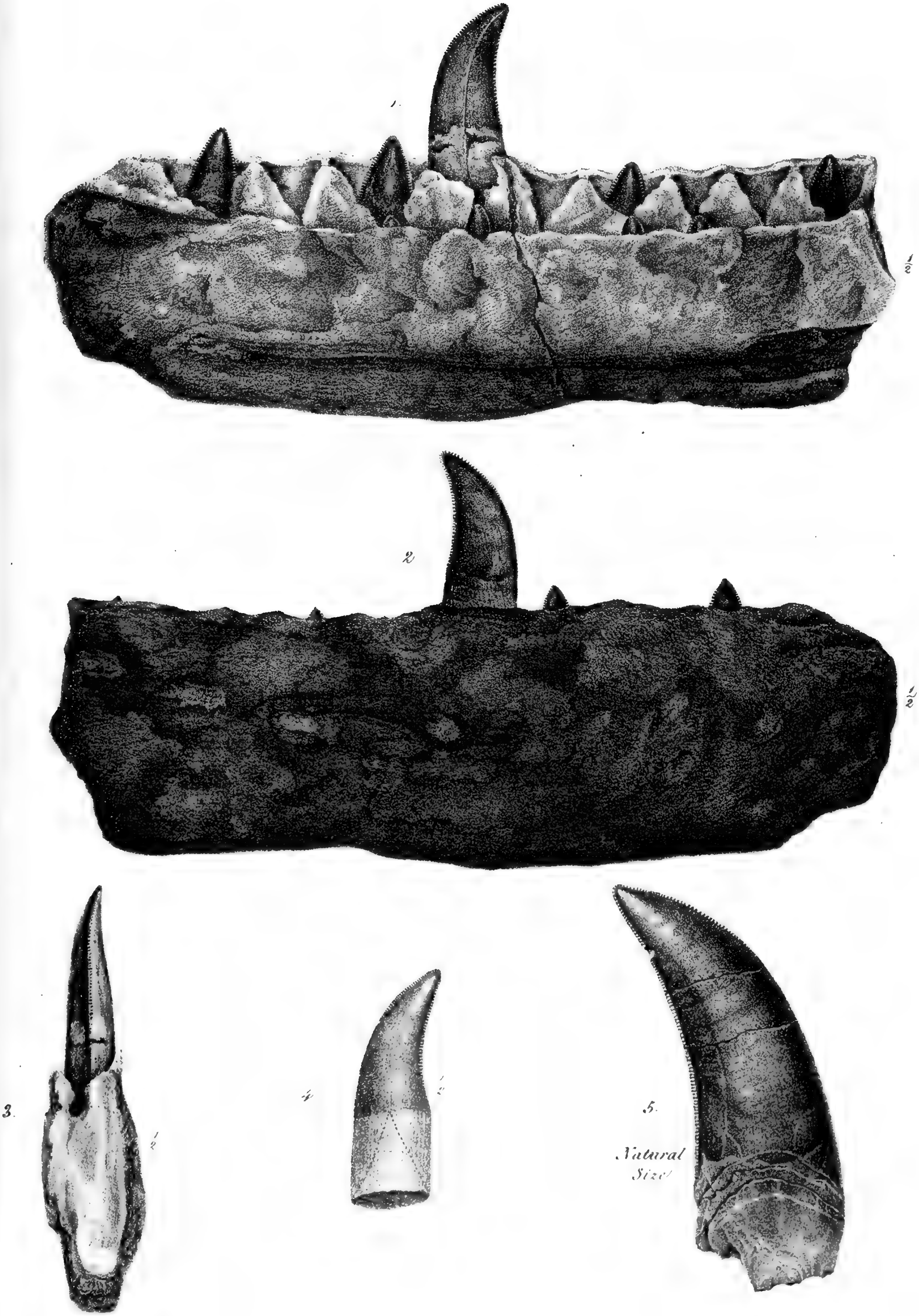
Scale of

Dra... by M. Morland & on Stone by Henry Per...

LOWER JAW OF THE MEGALOSAURUS.

NEAR OXFORD.

Printed by C. Hullmandel.

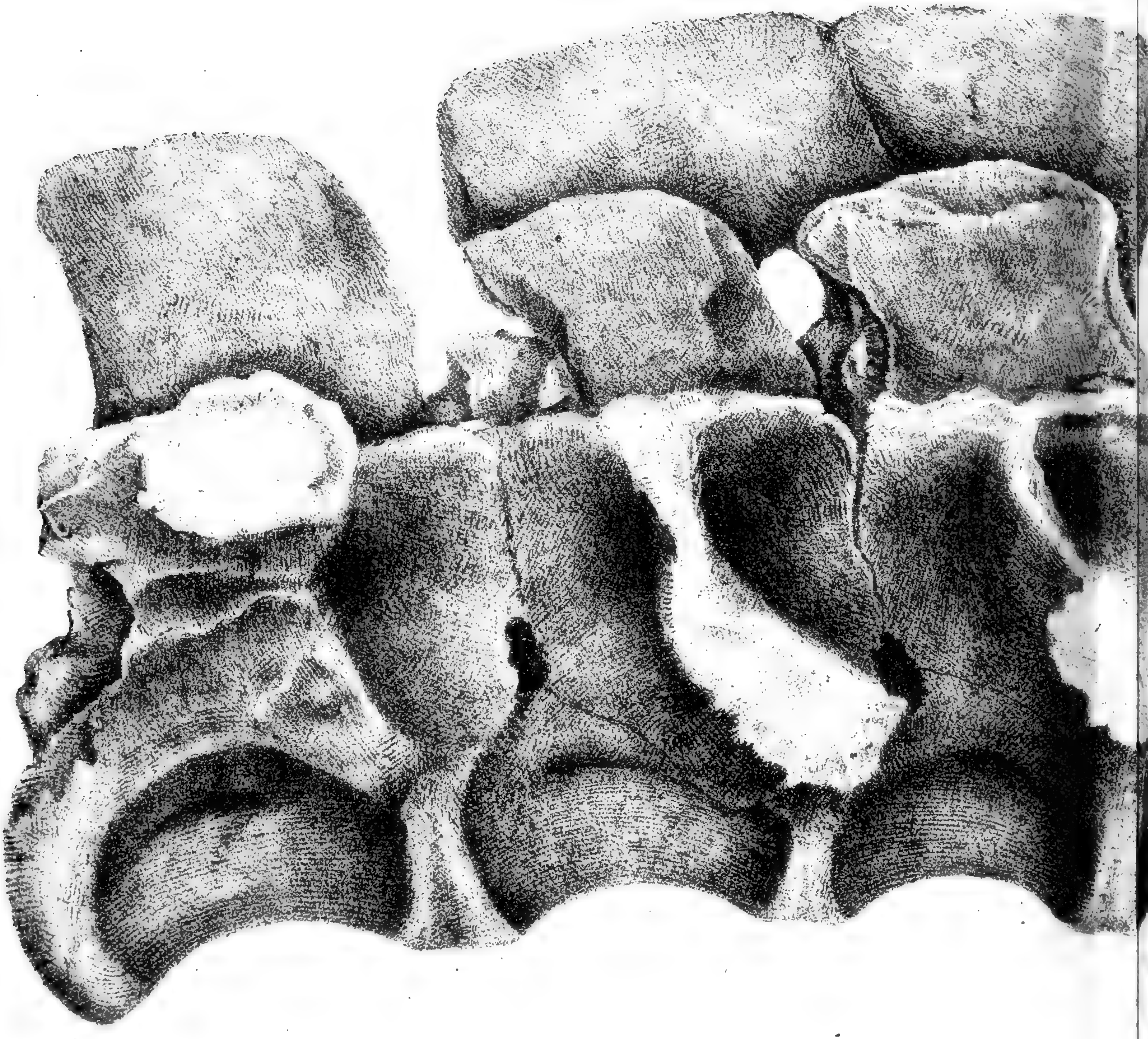


UNDER JAW AND TEETH OF MEGALOSAURUS.

0 3 6 9 12

Scale ½ Inch to One Inch

1.

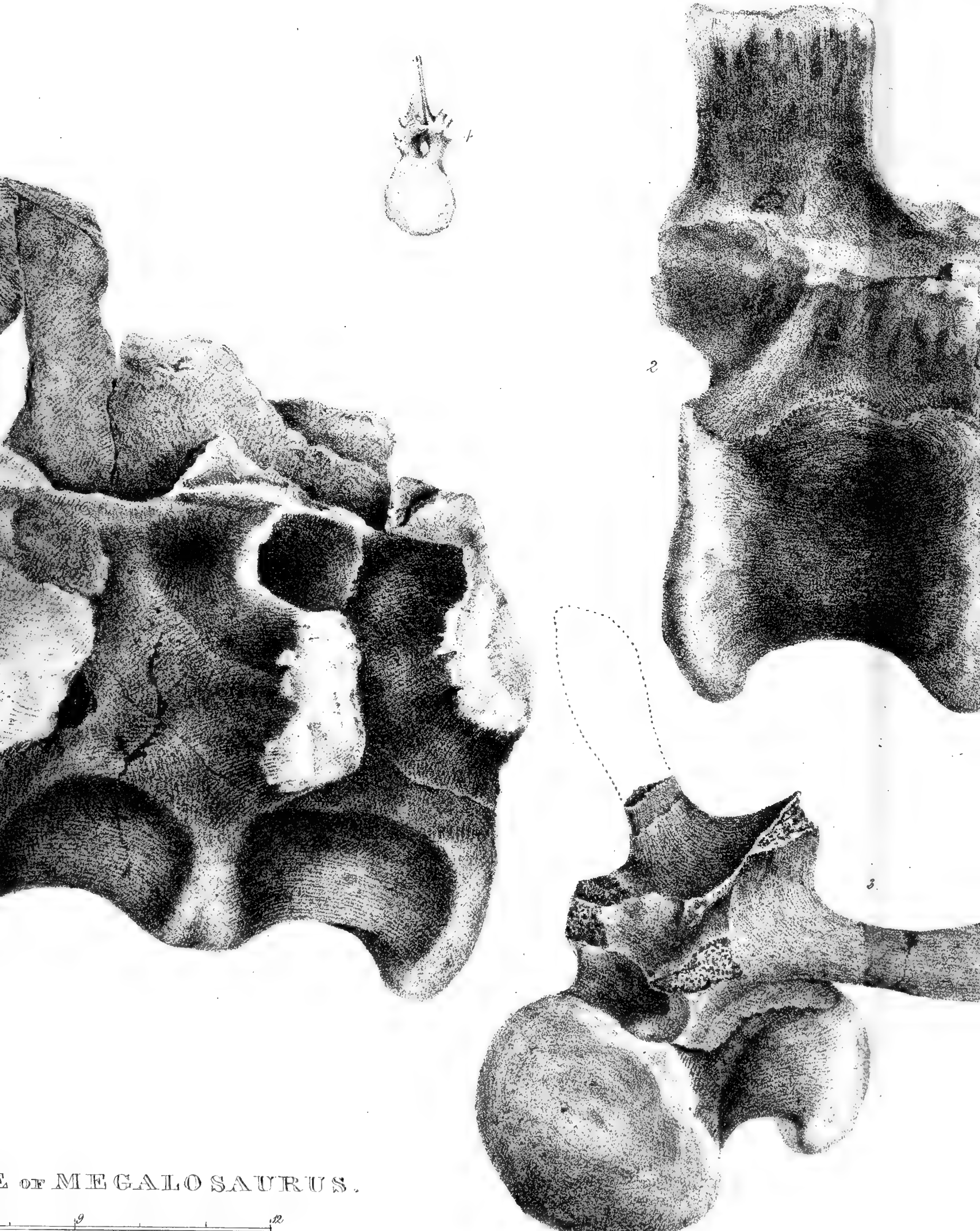


SACRAL LUMBAR & CAUDAL VERTEBR

Drawn by M. Morland. & on Stone by Henry Perry.

0 3 6

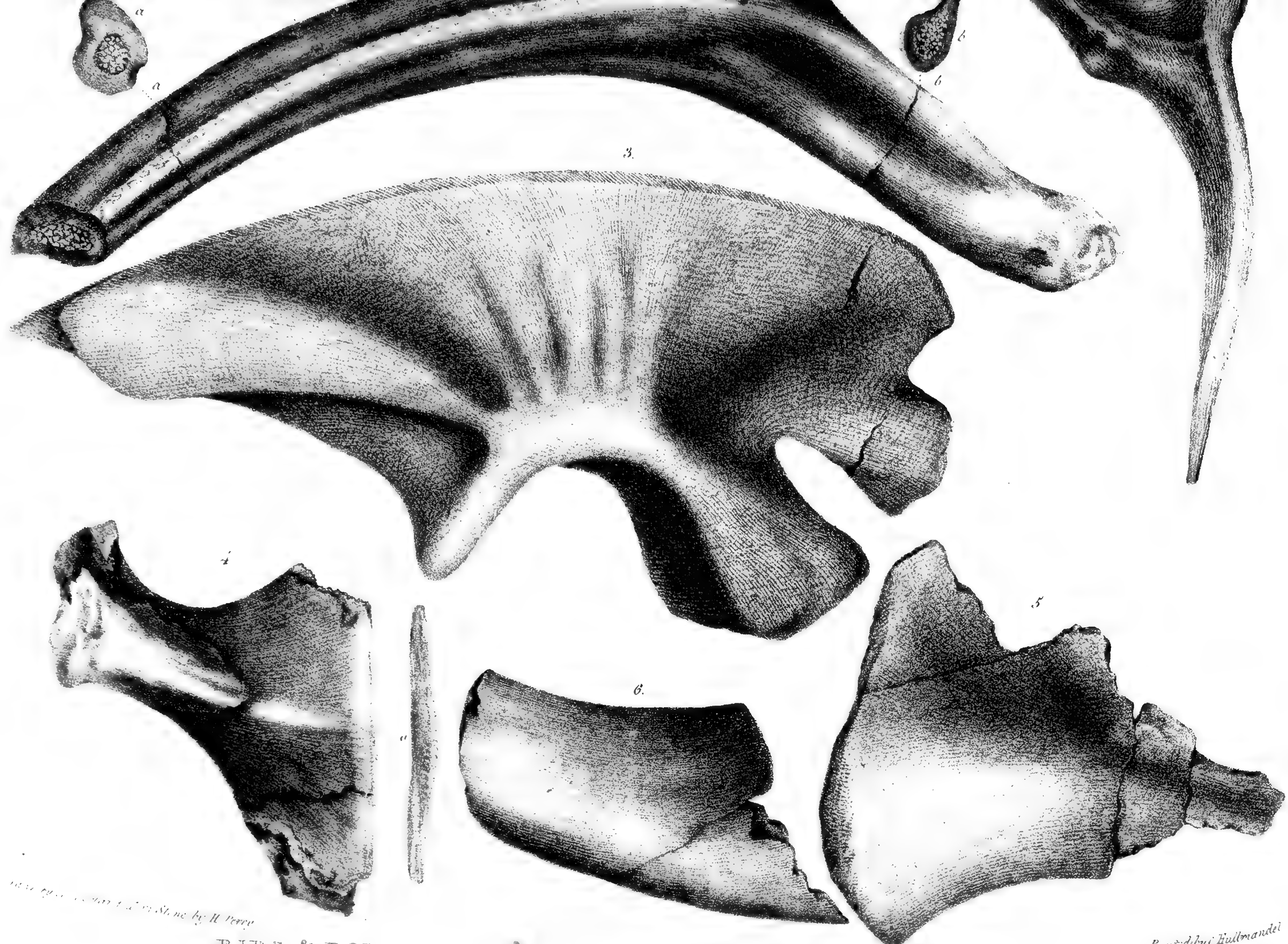
Scale ½ an Inch to an Inc



E OF MEGALOSAURUS.

9 12

Printed by



Drawn by ... on Stone by H. Perry

Printed by C. Hullmandel

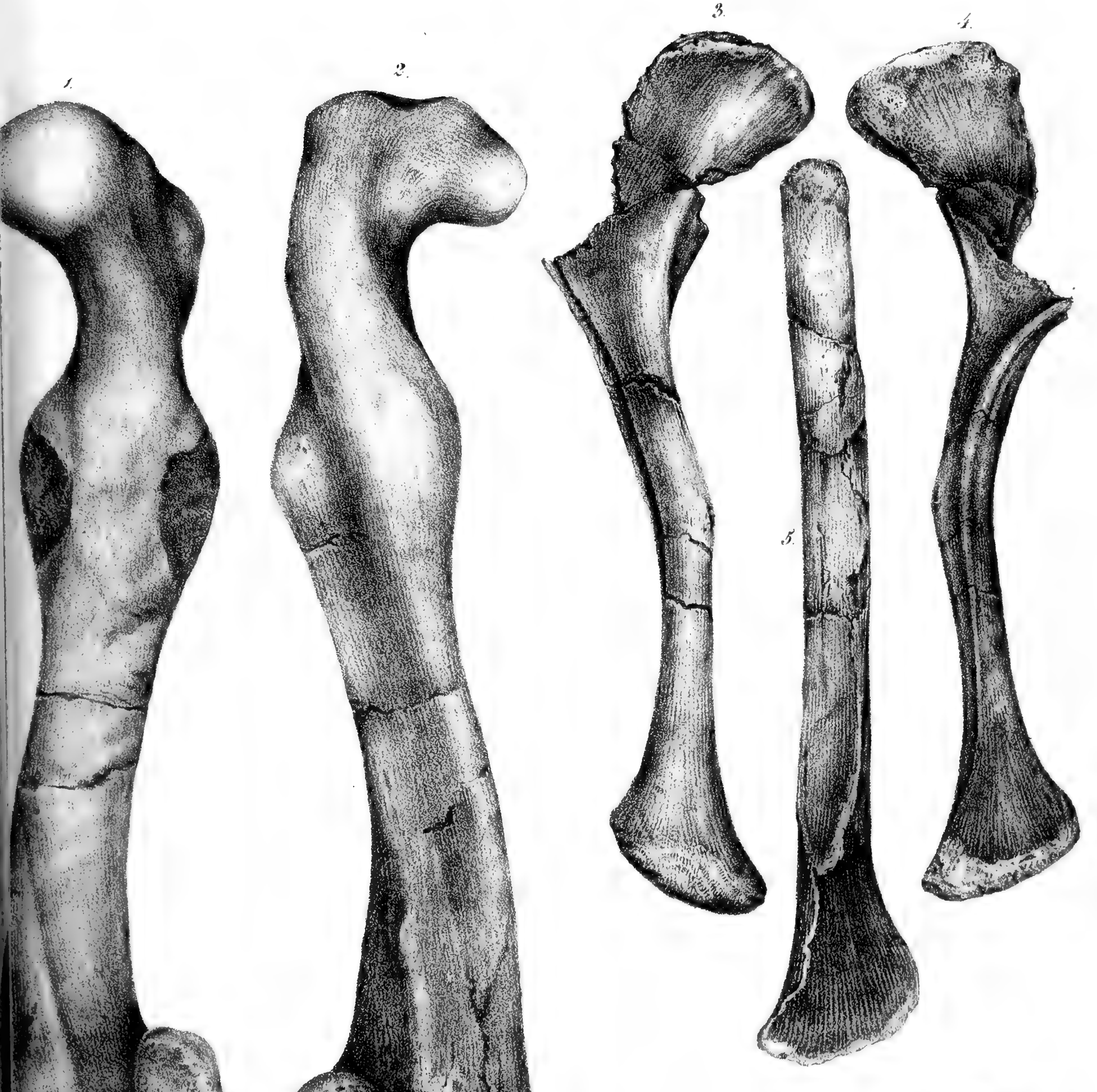
RIBS & BONES OF THE PELVIS & SCAPULA OF MEGALOSAURUS.

3 6 9 12 in

Fig.s 1. 2. 4. Scale ½ Inch to One Inch

3 6 9 12

Fig.s 3. 5. 6. Scale 1 Inch to One Inch

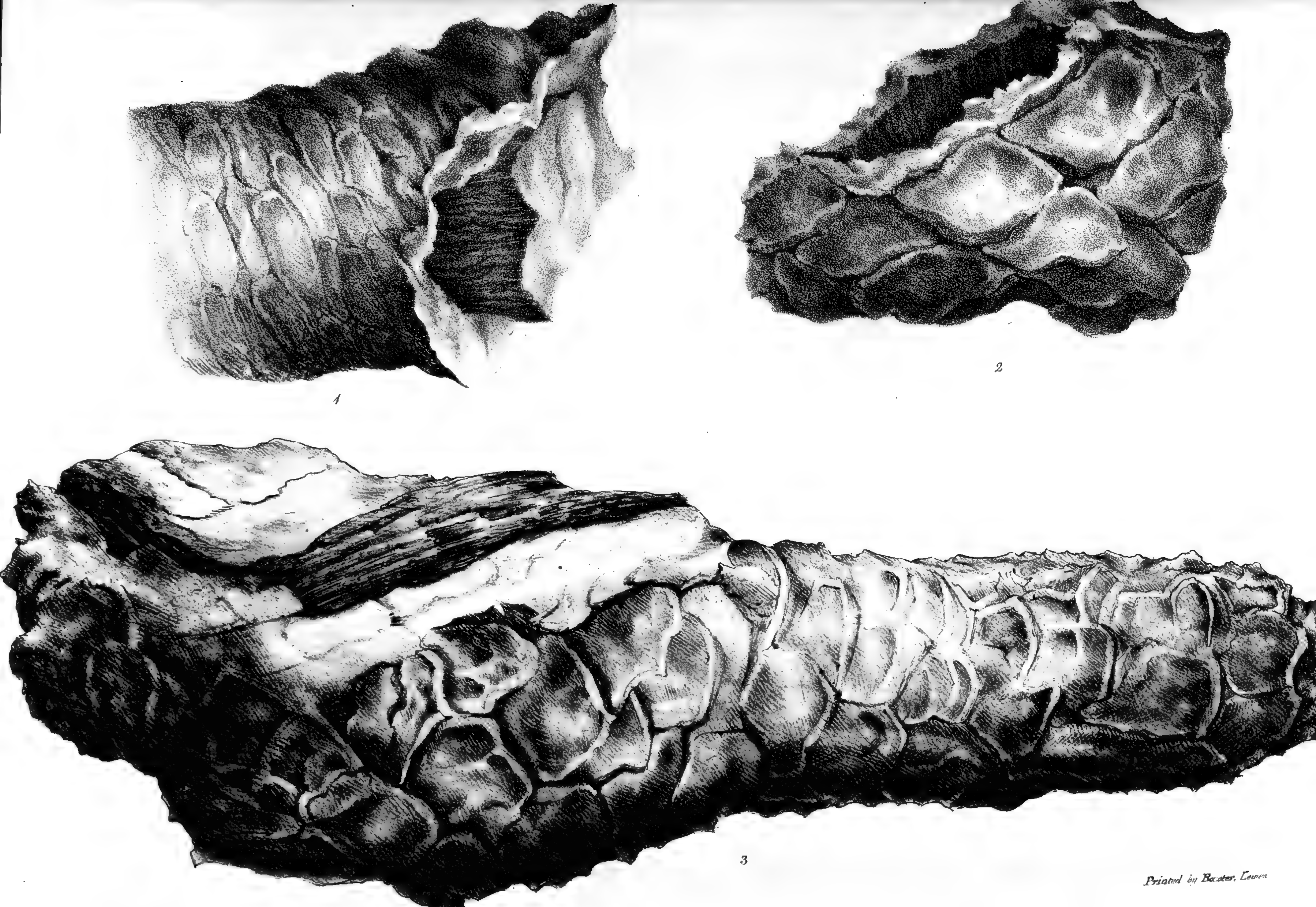


FEMUR CLAVICLE, FIBULA & METATARSAL BONE OF MEGALOSAURUS.

Scale ¼ Inch to One Inch

rawn by M. Morland, & on Stone by Henry Perry

Printed by C. Hullmandel



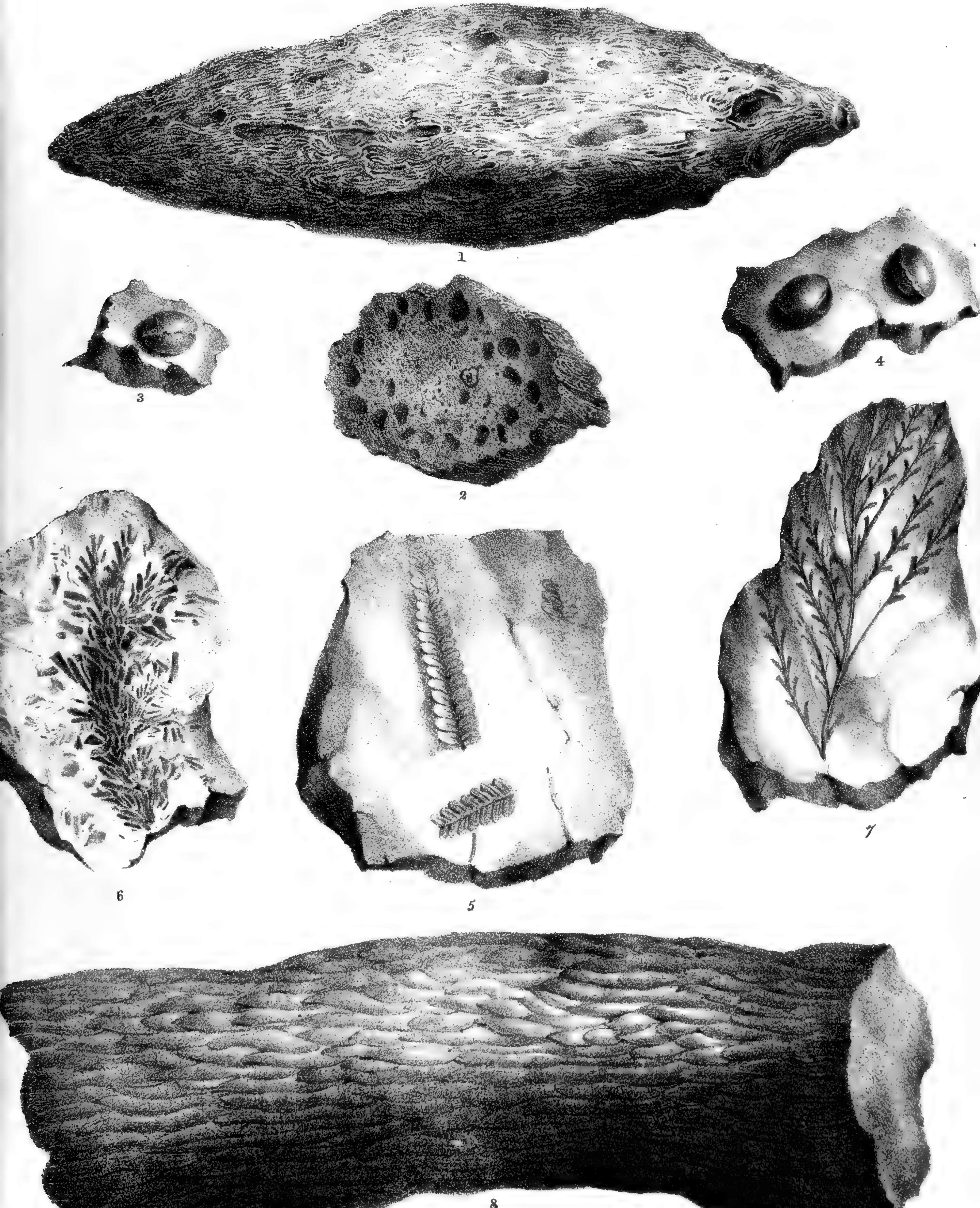
1

2

3

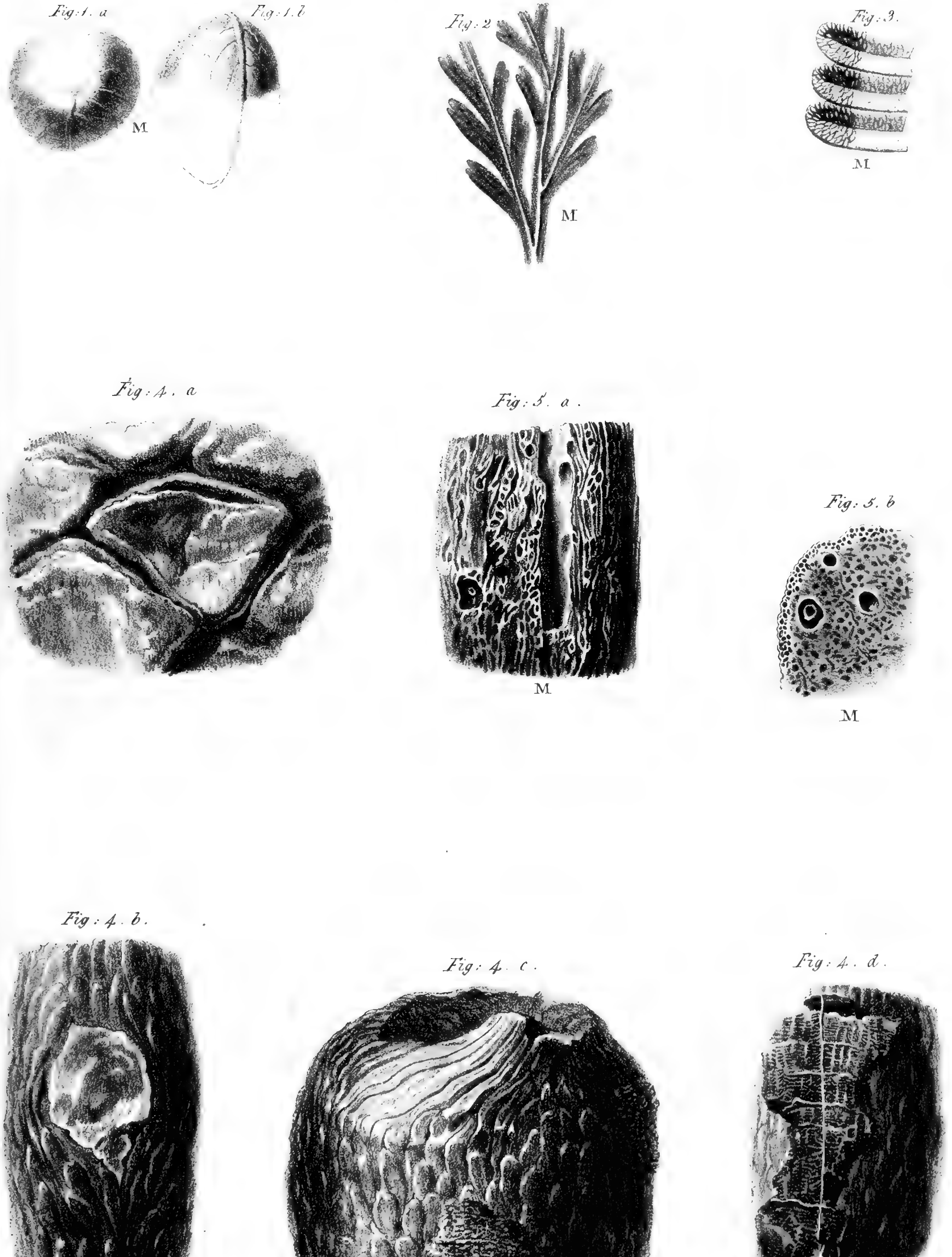
E. Pollard Del.

Printed by Baxter, Lewes



F. Pollard. Del

Printed by Baxter, Lewes.



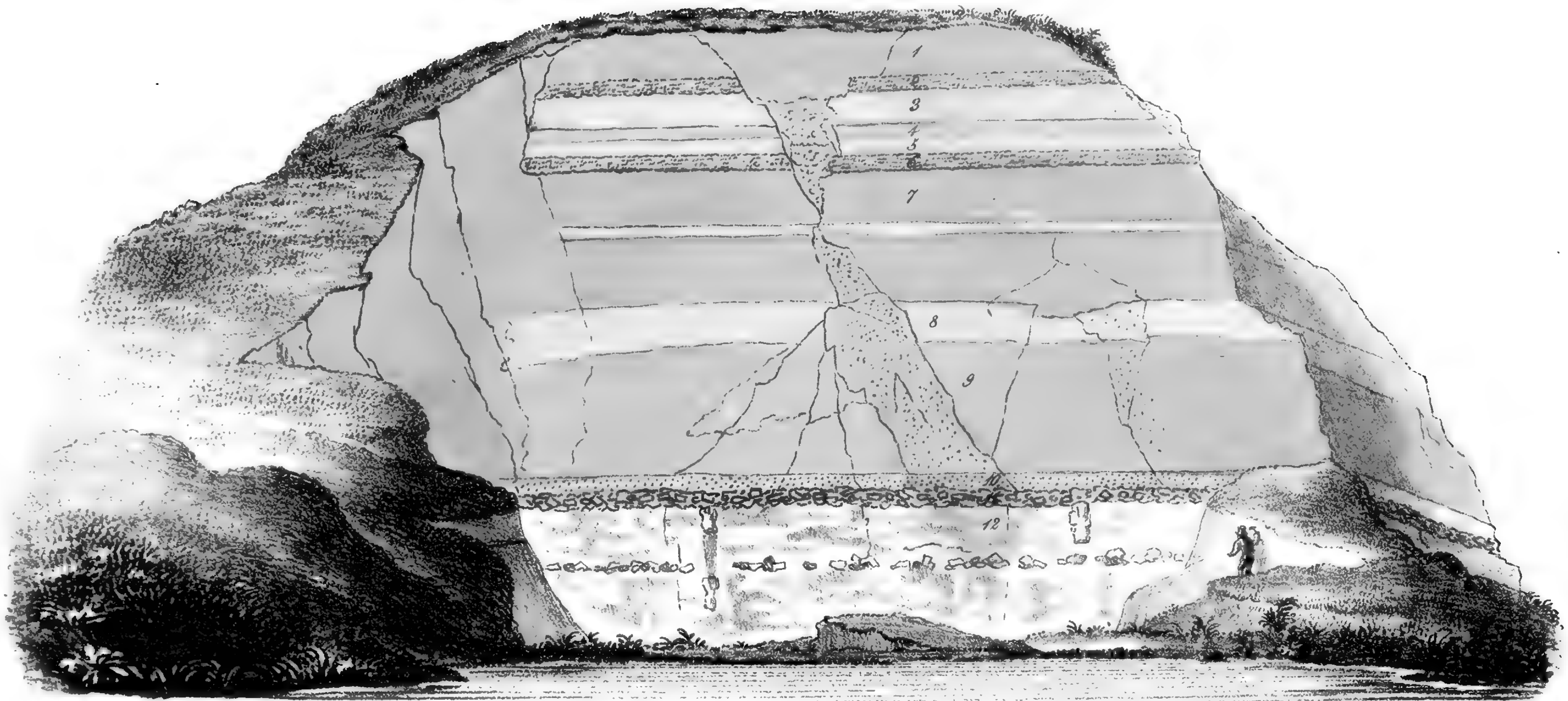
G. Scharf delt et lithog

Printed by C. Hullmandel

PORTIONS OF FOSSIL PLANTS,

FROM TILGATE FOREST, NEAR CUCKFIELD, SUSSEX.

Represented in Plates 45 & 46. Those marked M, are magnified.

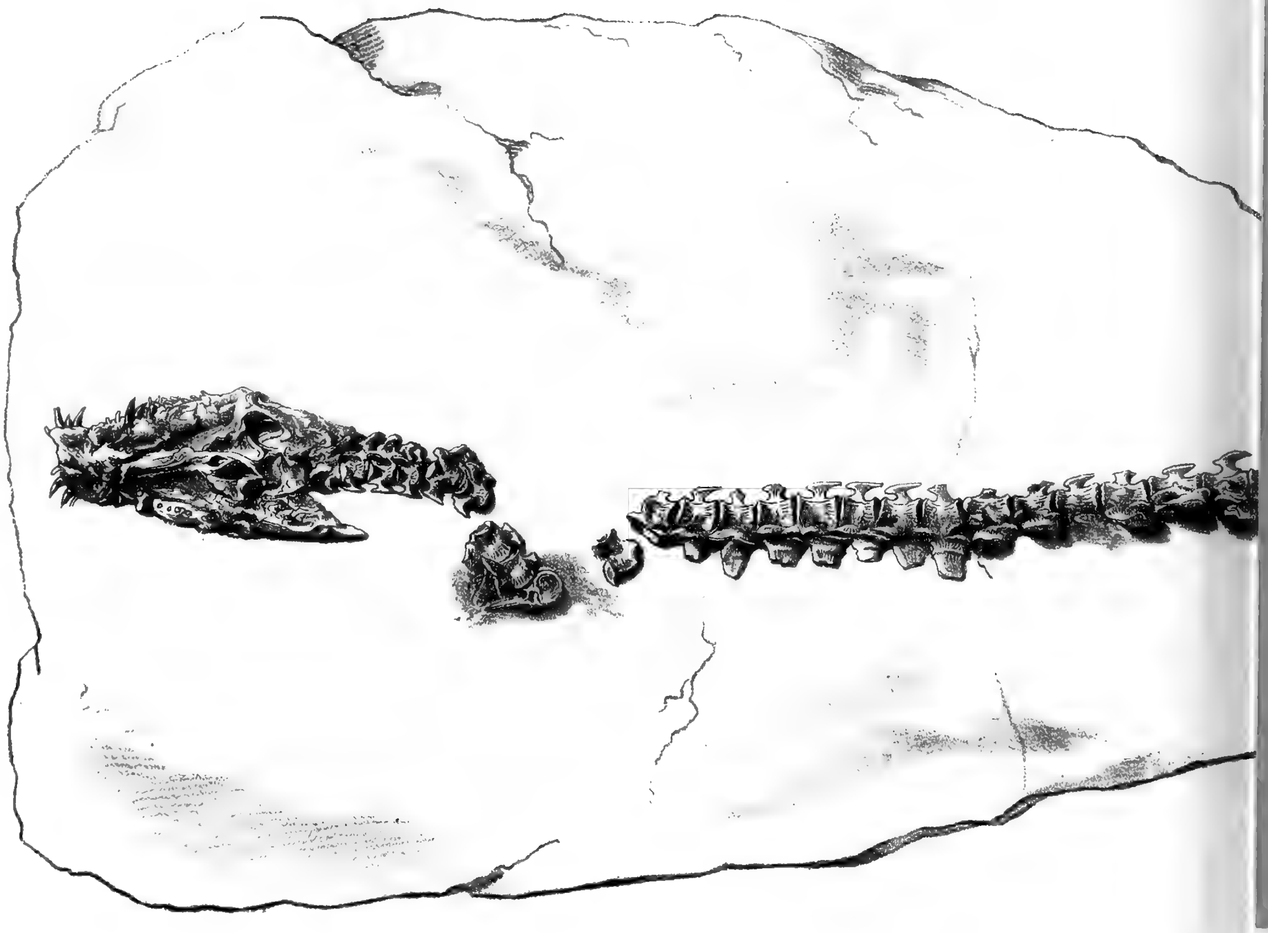


SECTION of the CRAG STRATA at BRAMERTON near NORWICH.

Drawn by R. Taylor

Printed by C. Hullmandel

G. Scharf Lithog.



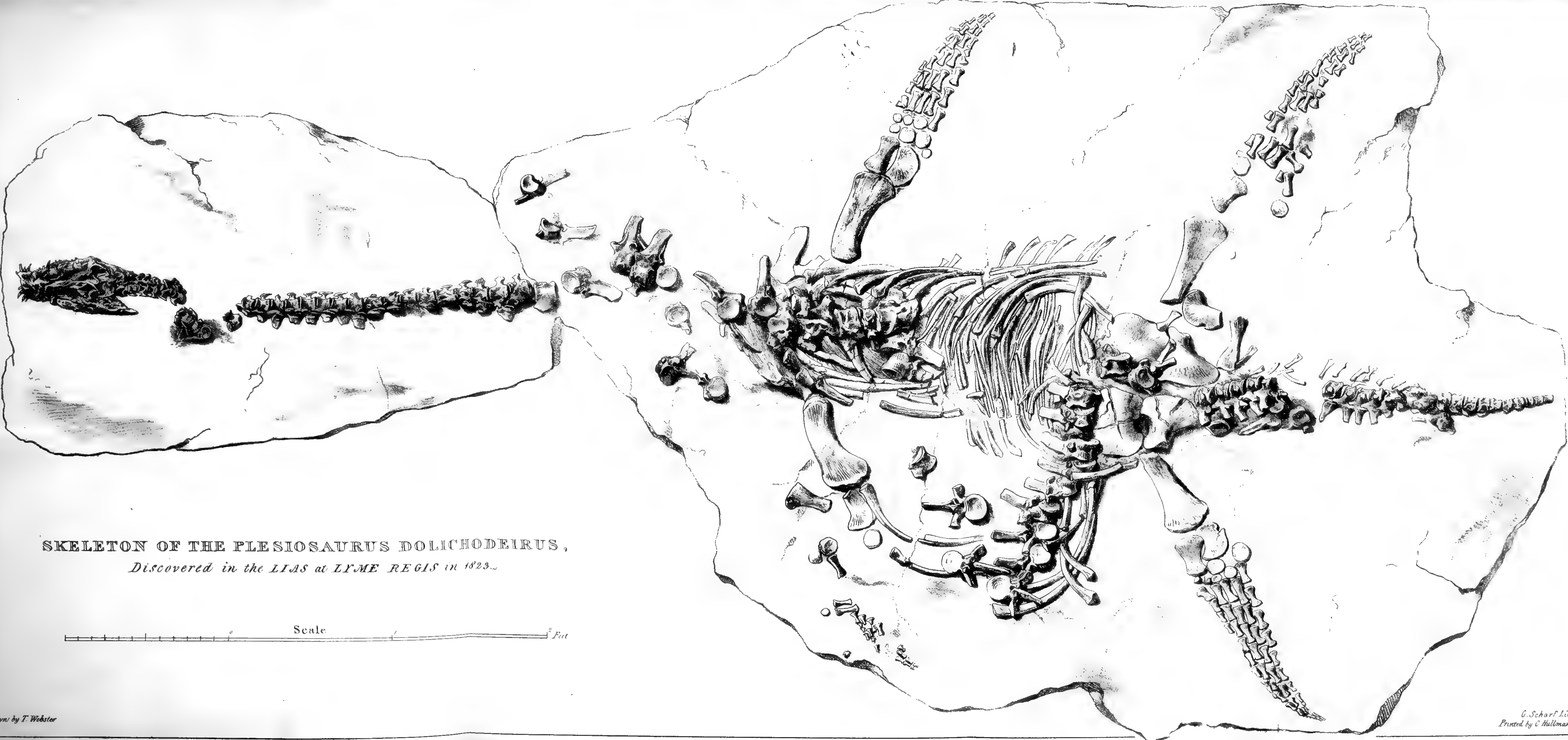
SKELETON OF THE PLESIOSAURUS DOLICHOD

Discovered in the LIAS at LYME REGIS in 1823.

Scale.

0 1

Drawn by T. Webster



SKELETON OF THE PLESIOSAURUS DOLICHODEIRUS,

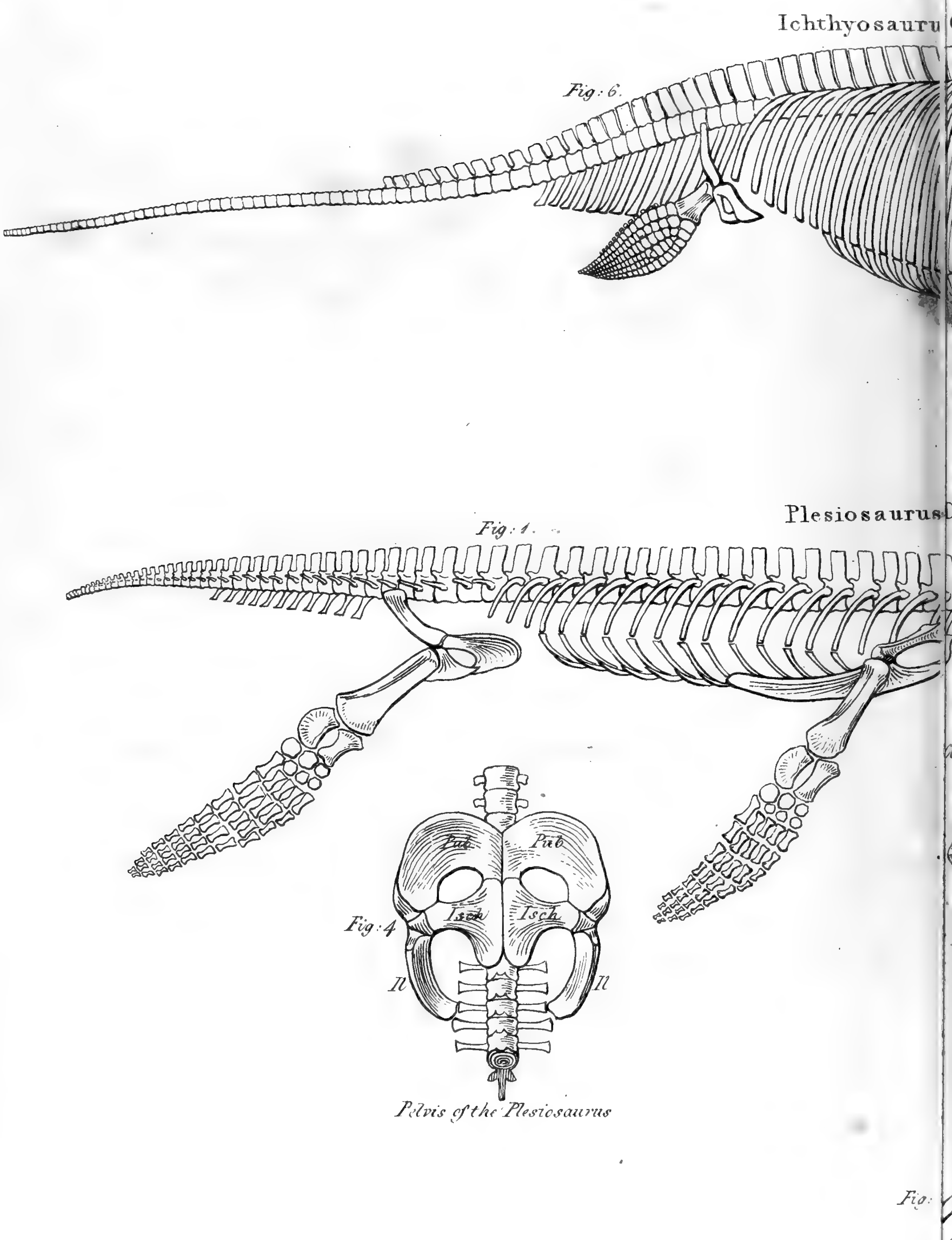
Discovered in the LIAS at LYME REGIS in 1823.

Scale

0 1 2 Feet

Drawn by T. Webster

G. Scharf Lithog.
Printed by C. Hullmandel

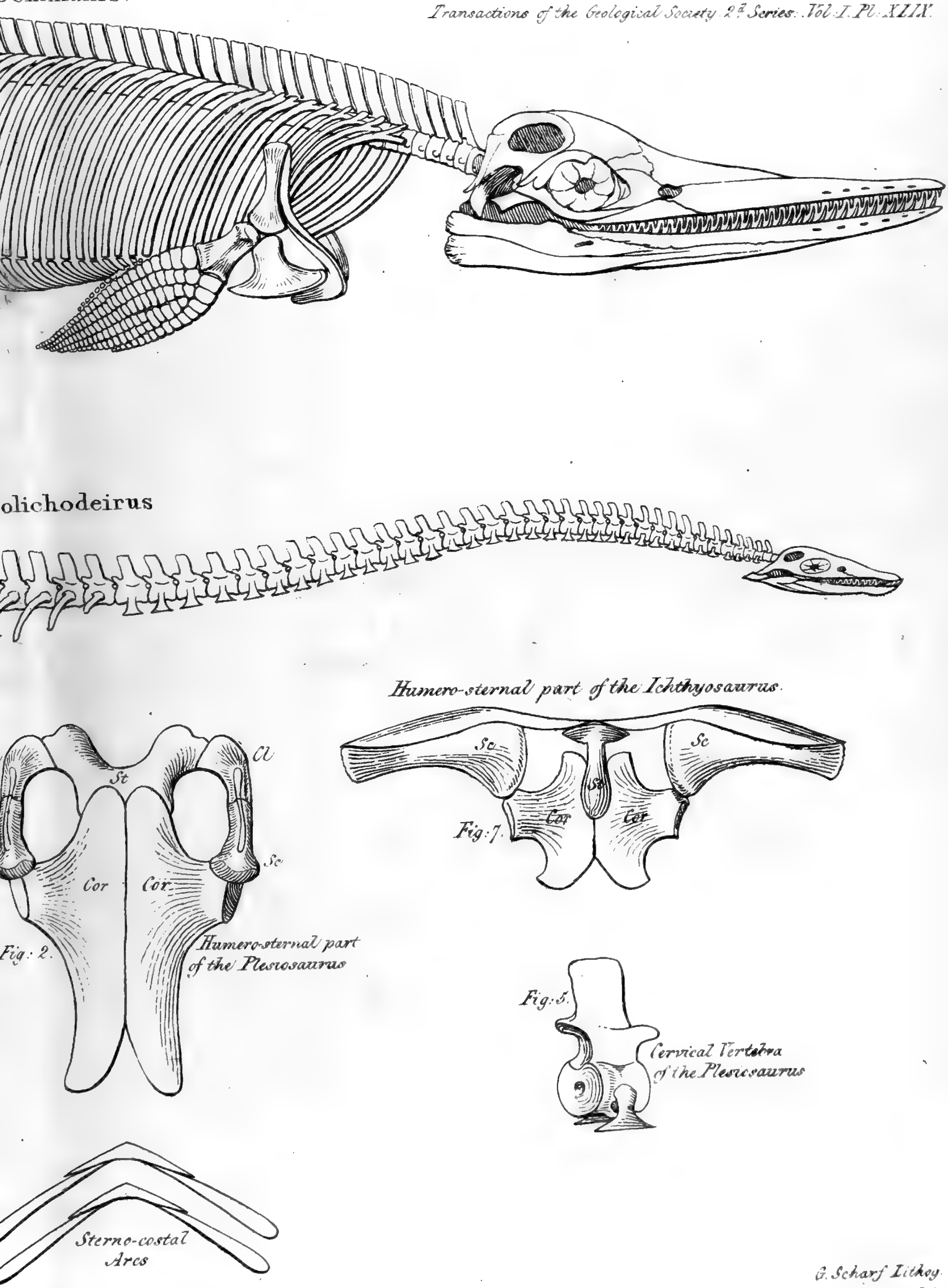


Pelvis of the Plesiosaurus

Drawn by the Revd W D Conybeare

RESTORATION OF THE PLESIOSAURUS DOLI

Communis.



HODEIRUS, AND ICHTHYOSAURUS COMMUNIS.

G. Scharf Lithog.
Printed by C. Hullmandel

24